The Effectiveness of a Comprehensive School-Based Caries Prevention Program: ForsythKids

The Effectiveness of a Comprehensive School-based Caries Prevention Program: ForsythKids

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Abstract

The aims of this dissertation are to describe ForsythKids program; evaluate the longitudinal temporal trends in the incidence of new caries over time; to propose a new metric that measures dental health preservation as an outcome: Proportion of Sound Teeth index (PST).

We analyzed the data extracted from the clinical notes of ForsythKids, a school-based comprehensive dental preventive program. ForsythKids was first implemented back in 2004 in six Title 1 elementary schools in greater Boston area, followed by over 60 schools. Children participating in ForsythKids were eligible to receive three annual school visits, where they will receive full clinical examination and treatment planning, a range of preventive measures, and a referral to a community dentist if needed.

All children aged 5-12 years seen between 2004-2010 were eligible for inclusion in the analysis. We assessed baseline demographic characteristics, and baseline oral health of participating students. Then we fitted multiple regression models to estimate the incidence rate ratio (IRR) of developing new dental caries with each additional preventive visit. We also measured the time and risk to the first dental caries during ForsythKids among caries-free children at baseline and children with caries experience. In addition, we proposed a new metric that measures dental health instead of disease: Proportion of Sound Teeth index (PST). We describe how to calculate the different variations of PST: cross-sectional (xPST), instantaneous (iPST), and cumulative (cPST); then applied xPST and cPST to evaluate ForsythKids data; and

compared the results to those obtained with the conventional index, decayed and filled teeth (DFT).

More than half of the children had caries before joining ForsythKids, with 1.9 decayed and filled teeth (dft) in primary teeth (xPst=83.6% sound teeth), and 0.4 DFT in permanent teeth (xPST=98.7%). Overall, each additional preventive visit was associated with an 8% reduction in new dental caries, and the reduction of was steeper among children high-risk children with caries experience at baseline. However, those children had 2.5 times the hazard of developing the first caries compared to their caries-free peers at baseline (95%CI= 2.2, 2.7).

For PST over time, the average reduction in cPst was 3.7 percentage points per visit in primary dentition and 1.6-point reduction in cPST for permanent dentition. Children with caries experience at baseline had a steeper reduction in cPST, while caries-free children had a steeper increase in DFT scores.

In summary, within the limitation of the clinical data and potential selection bias of the participants, the comprehensive nature of ForsythKids appears to lower the incidence of dental caries with each preventive visit, maintain dental health for longer, especially among high-risk children with caries experience at baseline.

Specific Aims

The 2000 surgeon general report states that oral health is an integral part of overall health (U.S. Department of Health and Human Services 2000). Dental care accounts for 11.4% of U.S. health expenditure among school-children, and 90% of children have dental coverage. Still, almost 1 out of 5 school-children suffers from untreated dental caries, and more than half of the children did not visit a dentist in the previous year (Kamyar Nasseh and Marko Vujicic 2016, Bui, Dieleman et al. 2017, National Center for Health Statistics 2017).

Dental caries is a chronic sequala of a bacterial infection. It is the most prevalent disease in the United States, despite the fact that it can be prevented with available, safe and relatively inexpensive measures. In addition, dental caries unequally affects minority groups and vulnerable populations, who have higher caries incidence and severity. Therefore, these high-risk groups have been targeted for preventive dental services, and reduction of this disparity has been incorporated in the targets of the national initiative Healthy People 2020 (U.S. Department of Health and Human Services and Office of Disease Prevention and Health Promotion 2014).

ForsythKids is a school-based dental prevention program initiated in the spring of 2004 with a total of 6 elementary schools in greater Boston area. By 2020, ForsythKids was serving close to 60 pre-K, elementary, middle, and high schools around greater Boston. The program targets high-risk children and aims to improve access and reduce dental caries by providing comprehensive preventive services ranging from oral hygiene instruction to sealants and referrals for active dental disease. We will retrospectively analyze the first 6 years of ForsythKids data from 2004-2010 to address the following aims:

1. To describe the ForsythKids program, baseline demographic characteristics, and baseline oral health of participating students
2. To determine longitudinal temporal trends in the incidence of new caries over elapsed time
3. To propose a new metric that measures dental health preservation as an outcome, Proportion of Sound Teeth index (PST), describe how to calculate the different variations of PST, apply it to evaluate ForsythKids data, and compare results to those obtained with the conventional index, decayed and filled teeth (DFT)

Overview

The topics covered in the following literature review focus on the age group 2-19 years, including children with primary, mixed, and up to 6 years of permanent dentition. The term "children" in the introduction includes both children and adolescents. That is, unless further specified, "children" could include all people 19 years of age and younger.

"Caries experience" is defined as a value larger than 0 in decayed, filled index (df) score for the primary dentition and Decayed, Missing, Filled index (DMF) score for the permanent dentition. Caries experience represents current and past dental disease. In contrast, "untreated caries" represents the decayed component only, emphasizing the presence of active disease, often (though not always) reflecting unmet need or lack of access to dental services.

Following the overview is a series of stand-alone manuscripts, which explain why there might be some repetition.

1. Dental Caries Prevalence and Trends

Dental caries is the most prevalent disease in the world, affecting more than 3 billion people globally with active disease (Kassebaum, Bernabe et al. 2015, Kassebaum, Smith et al. 2017). Despite the great advancements in dental technologies in the last 25 years, the age-adjusted prevalence and incidence of untreated dental caries remained almost the same worldwide from 1990 to 2015 (Kassebaum, Smith et al. 2017). Temporal trends in caries experience are not very different in the United States than the rest of the world. After a steep decline in caries prevalence following the introduction of community water fluoridation in 1945, the rate of reduction of caries in both primary and permanent teeth slowed down since

1990s (Ripa 1993, U.S. Department of Health and Human Services and Office of Disease Prevention and Health Promotion 2014, Rozier, White et al. 2017).

a. Caries Experience

i. 2-6-Year-old Children (Primary Dentition)

Caries experience remained the same since the early 1990s. National surveys indicate a stagnated ratio of one out of 4 pre-school children experiencing caries in in their primary teeth. Furthermore, the average dfs score among pre-school children was 2.6 surfaces in 2011-2014, a 23% increase from 2.2 in 1988-1994 **(Figure 1.0)** (Rozier, White et al. 2017, Oliveira, Rajendra et al. 2018).

ii. 6-17-Year-old Children (Mixed and Permanent Dentition)

By the time children are 11, almost half have experienced dental decay in their primary teeth; average dfs scores increased from 3.5 surfaces in 1988-1994 to 4.8 surfaces in 2011-2014. In the permanent teeth, the prevalence of caries experience seems to have dropped among younger children from 26% in 1988-1994 to 18% in 2011-2014, and among older children aged 12-17, from 64% to 52% over the same period. However, the average DMFS score remined constant since 1999-2004 at 0.7 surfaces among younger children and 3.5 surfaces among children 12-17 years **(Figure 1.0)** (Slade and Sanders 2017). This discrepancy could suggest the presence of disparity in caries experience, with an increase in severity of disease among a concentrated high-risk group who suffer most of the disease burden even as fewer children have any caries overall.

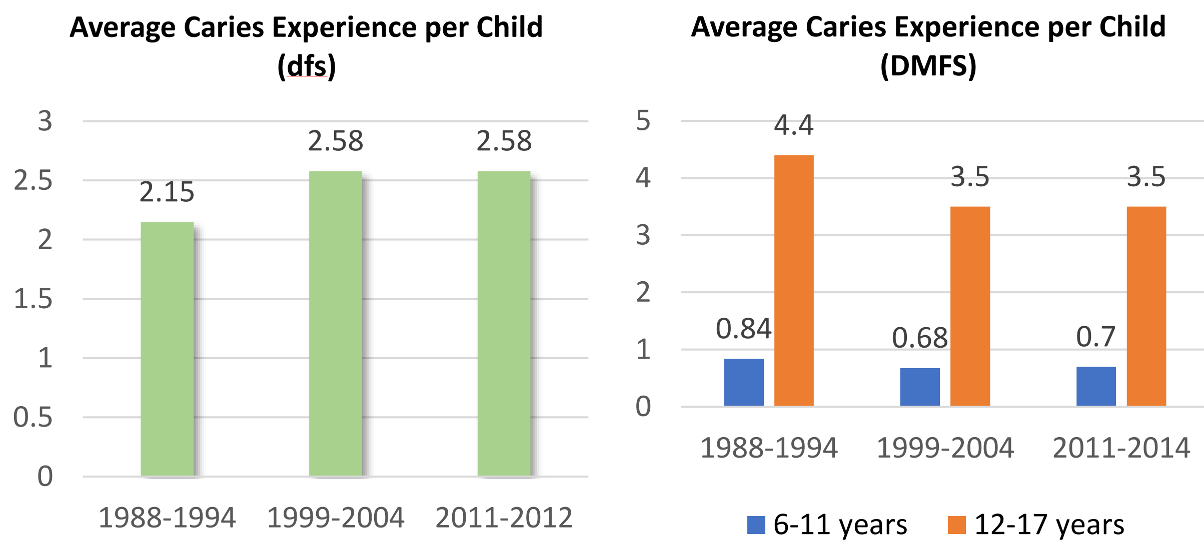


Figure 1.0: The average caries experience per dentition over the years

b. Untreated Caries

During the 2010s, the prevalence of untreated caries decreased markedly, in both primary and permanent teeth, by almost half. Among 3- to 5-year-old children, the prevalence of untreated caries in the primary teeth decreased from 23.8% in 1999-2004 to 11.7% in 2011-2014 **(Figure 2.0)** (U.S. Department of Health and Human Services and Office of Disease Prevention and Health Promotion 2014). Untreated caries in permanent teeth also decreased but to a lesser degree, from 22.5% in 1999-2002 to 16.6% in 2005-2008, and it increased in 2011-2014 to 18.6% **(Figure 2.0)** (National Center for Health Statistics 2017).

The sudden drop in prevalence of untreated caries in the early 2000's could be explained by, among other factors, the signing of the Children's Health Insurance Program (CHIP) into law in 1997, which may have improved access to care (Manski, Moeller et al. 2001, Kamyar Nasseh and Marko Vujicic 2016). As a result, untreated caries may have shifted to the other components of DMFS index, in this case the filled component, and didn't necessarily prevent the incidence of the disease nor promoted health.

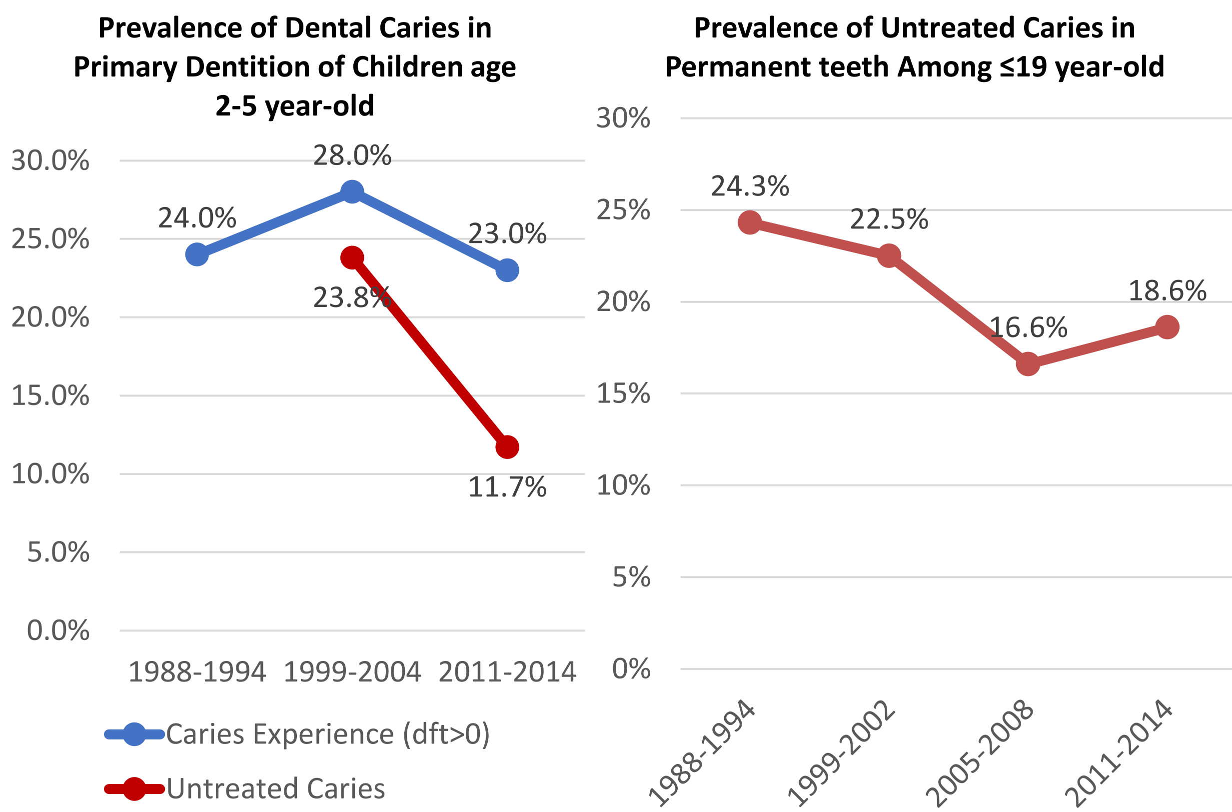


Figure 1.0: The prevalence of caries per dentition over the years

2. Risk Factors for Dental Caries

Dental caries is directly caused by bacterial attachment to a tooth surface with the presence of fermentable carbohydrates over time. In addition, more distant environmental, socio-demographic, economic and even genetic factors interact to determine the risk of dental caries (Wang, Willing et al. 2012). These risk factors can be classified, based on the social determinants of health, to individual, household and environmental factors.

For example, having a dental visit during the last 12 months is an individual-level risk factor associated to a lower untreated caries among children (Gupta, Vujicic et al. 2018). Access to periodic routine, non-emergency, dental visits provide the child with preventive care to reduce tooth decay, as well as a chance for an early conservative intervention if decayed. In addition, children with a history of caries are at a higher risk for future caries (American Academy of Pediatric 2013).

Among household-level factors are family income and education level of caregivers, which is inversely associated with untreated dental caries (Psoter, Pendrys et al. 2006, National Center for Health Statistics 2017). In addition, Immigration status of the family is another house-hold factor associated with dental diseases, making children of families recently immigrated at higher risk to develop dental caries (American Academy of Pediatric 2013). Several hypotheses could explain the household-level associations. For instance, lower oral health literacy of care caregivers can contribute to dental diseases in the children. In the case of new immigrants, they could be challenged by navigating the new health system and access to dental services.

Caries is also disproportionally distributed geographically, with higher proportion and severity of untreated caries among children living in rural areas and living in communities with sub-optimal community water fluoride concentration (Krol 2003, Dawkins, Michimi et al. 2013, Walker, Probst et al. 2014). These environmental-level factors may be affected by health-related policies, like insurance coverage or reimbursement rates, and the distribution of dental providers.

3. Adverse Outcomes Associated with Dental Caries

a. Physical and Psychological Outcomes

The consequences of dental diseases are not isolated to the oral cavity, rather they can influence all three components of overall health defined by WHO; physical, mental and social well-being. Caries-triggered pain and the destruction of tooth structure result from longstanding negligence of oral hygiene that directly affects both jaw function and facial appearance and indirectly affects both a child's quality of life. Dental caries affects chewing ability by reducing masticatory force and could potentially affect children's dietary intake (Kaya, Akyuz et al. 2017).

In the social context, dental health been associated with children's mental well-being and self-esteem. Students with dental problems are more likely to be shy and to feel worthless, unhappy, or less friendly. The strength of the association was found to be age dependent, as these association found to be stronger in older children compared to younger age group (Guarnizo-Herreno and Wehby 2012).

b. Academic Performance

Unmet dental need and dental pain among students were found to be associated with missing more school days, and with their parents' missing work to accompany their children to receive dental care (Seirawan, Faust et al. 2012, Agaku, Olutola et al. 2015). In addition to school absenteeism, lower academic performance is associated with the presence of dental diseases. Children who reported toothache within six months have lower average GPA and are less likely to complete their homework compared with children who had not experienced dental problems within the same time (Guarnizo-Herreno and Wehby 2012, Seirawan, Faust et al. 2012).

c. Overall Quality of Life

Other studies have been conducted to capture the overall effect of oral disease. The Oral Health-related Quality of Life -OHRQoL- survey is a multidimensional tool to measure oral health related functions, discomfort, environmental, social and psychological factors (Sischo and Broder 2011). Higher caries experience is associated with a worst OHRQoL score, for both children and their families (Gomes, Pinto-Sarmento et al. 2014, Alsumait, ElSalhy et al. 2015, Martins, Sardenberg et al. 2015, Mota-Veloso, Soares et al. 2016). However, Most of the OHRQoL literature were performed in Brazil, with virtually no reports of empirical studies using this tool in United States.

The Disability-Adjusted Life Years (DALYs) is an indicator to measure years of life lost to not living in a state of perfect health (Murray 1994). An estimated 7.26 DALYs are lost per 100,000 U.S. children younger than 5 years due to untreated caries in primary teeth. In comparison, in the same study, autism and diabetes mellitus were associated with an estimated loss of 62.72 and 9.86 DALYs per 100,000 children in the same age group, respectively. Caries in permanent teeth is associated with 13.63 DALYs lost per 100,000 children younger than 15 years. Children in a similar age group were estimated a loss of 92.04 and 22.94 DALYs per 100,000 for autism and diabetes, respectively (Institute for Health Metrics and Evaluation (IHME) 2017).

4. Preventive Measures for Dental Caries

Dental caries is not a single distinct state of disease, rather it is a spectrum of states of tooth destruction from demineralization of hard tissues to pulpal involvement (Featherstone 2004). It is a chronic condition that can vary from a subclinical state, with no observable signs or symptoms, to severe pain and loss of function over months. The typically gradual disease progression provides a wide window of opportunity to intervene to prevent, slow down, or even reverse dental caries with minimal non-invasive procedures.

Safe and effective preventive measures exist for a range of clinical contexts, from primary prevention in healthy children to tertiary prevention in patients with cavitated lesions (U.S. Department of Health and Human Services 2000, Quah and Cockerham 2017). Some measures are applied at the community level, such as water fluoridation. Measures applied at the individual level include those used at home, such as routine application of fluoride through tooth brushing, as well as professional procedures, including fluoride varnish application.

- **Community Water Fluoridation (CWF)** was named as one of the 10 public health achievements in the 20th century (Centers for Disease Control and Prevention 1999). It is the most effective measure to reduce the prevalence and severity of dental caries at a community level (U.S. Department of Health and Human Services 2016). Furthermore, CWF is the most cost-effective method to deliver fluoride to all the residents served by a community water supply, regardless of their social or economic status (Ran, Chattopadhyay et al. 2016). Currently, 74.4.3% of US population is served by a community water system delivering fluoridated water, the result of over seventy years of public health effort (Centers for Disease Control and Prevention 2014).

• **Oral Hygiene Education** is a behavioral intervention that aims to build self-efficacy and encourage better oral hygiene routines. It is assumed that if these practices are established at an early age, they are likely to persist to adulthood and prevent caries during the highest risk period (Aunger 2010). Oral hygiene education can be done at a population-level or one-to-one in the chair-side setting. It usually includes information about toothbrushing skills with fluoridated dentifrices, cariogenic diet counseling, supervised brushing, or a combination of measures.

Although oral hygiene education is widely implemented in primary school-based programs, a Cochrane systematic review found insufficient evidence that it reduces risk of caries. However, none of the interventions included in the study were based on behavioral theories (Cooper, O'Malley et al. 2013).

• **Fluoride Mouth rinse:** Weekly, supervised, school-based rinsing programs were popular in countries with high caries experience until the late 1980s. Then, doubts about their effectiveness followed the decline in prevalence of dental caries (Stamm, Bohannan et al. 1984, Disney, Bohannan et al. 1990). The current recommendation for such programs is restricted only to high-risk children (Commission 2002). Sodium fluoride (NaF) is the most common used solution in supervised programs with 0.2% concentration containing 900ppm fluoride for weekly rinse. A less concentrated solution of 0.05% with 230ppm fluoride is available for consumer’s daily use.

A recent systematic review of the fluoridated mouth rinses literature concluded that supervised use in a school setting is associated with a large reduction in caries increment for permanent teeth (Marinho, Chong et al. 2016). However, there were no data reported on caries increment for primary dentition.

- **Pits and Fissure Sealants (PFS)** are flowable materials professionally applied as physical barriers to block nutrients and biofilm growth in the pits and fissures of the teeth. PFS were introduced in the 1960s for primary prevention. More recently, PFS have also been adopted as a secondary preventive agent in controlling initial non-cavitated caries on occlusal surfaces (Splieth, Ekstrand et al. 2010, Wright JT, Crall JJ et al. 2016). Other than cleaning and isolation of the occlusal surface, applying sealants requires minimally invasive preparation. Thus, it can be performed in a community setting. However, sealant application is technique sensitive, requiring a dry environment during placement and curing. The most commonly used materials are glass incomers and, more recently, resin-based sealants.

Other than CWF, school-based dental sealant delivery is the only oral preventive measure recommended by the Community Preventive Services Task Force (CPSTF) (The Community Guide 2013). In a systematic review, resin-based sealants were found to be effective in reducing occlusal caries up to 50% within 24-month follow up (Ahovuo-Saloranta, Forss et al. 2017). Similar effectiveness was observed at various timepoints within four years of sealant application, beyond which the quality of evidence was reduced. There is yet insufficient evidence available in the literature to evaluate the effectiveness of glass ionomer sealants, or to compare the effectiveness of different sealant types.

From an economic perspective, PFS are found to be both a cost-effective and cost-saving intervention (The Community Guide 2013). School-based sealant programs become cost-saving within 2 years after sealant placement, due to the averted costs of treating dental caries.

The economic benefit of PFS school-based programs are indicated to be even greater if they are implemented in school in which high risk students are concentrated.

- **Fluoride Varnish:** This form of professionally applied fluoride agent has the advantage of adhering to the tooth surface for a prolonged contact time and slowly releasing the fluoride. This reservoir mechanism prevents the loss of fluoride after application and reduces the chance of acute fluoride toxicity (Ogaard, Seppa et al. 1994). In addition, fluoride varnish is easy to use and relatively inexpensive, which makes it a suitable choice for community-based programs, including school settings, in moderate to high caries prevalence populations (Petersson L. G., Twetman S. et al. 1997). Fluoride varnish has been proposed as a primary or secondary preventive measure, to re-mineralize non-cavitated white lesions. Sodium fluoride 5% is the most used formula for varnishes, containing 22,600ppm of fluoride.

The effectiveness of fluoride varnish has been a topic of a vigorous research during the last 2 decades. The most updated Cochrane systematic review covered 22 clinical trials, in which more than 12,000 children had been randomized to receive either fluoride varnish, mostly applied twice a year, placebo, or no treatment. The DMFS and dmfs scores of were , on average, 43% and 37% lower among the varnish group (respectively) compared with the no-treatment group (Marinho, Worthington et al. 2013). In a meta-analysis of 4 clinical trials in which fluoride varnish was used to re-mineralize enamel early caries, 63.6% of lesions were reversed upon application of fluoride varnish (Gao, Zhang et al. 2016).

- **Atraumatic Restorative Treatment (ART)** consists of hand instrument excavation of tooth structure softened by dental caries, without local anesthesia. The tooth structure is then restored, usually with flowable glass ionomer materials. ART is used as a tertiary preventive measure to reduce the progression of the cavitated tooth surface. Since this approach does not use rotary instruments or local anesthesia, it minimizes anxiety and conserves tooth structure (Mickenautsch, Frencken et al. 2007). ART is the restoration of choice for behaviorally challenging patients or for clinical outreach programs in the community setting.

A meta-analysis of single-surface ART clinical trials found a high retention rate over 2 years for primary teeth and over 5 years for permanent teeth (de Amorim, Leal et al. 2012). For multiple-surface ART, the same systematic review concluded a low survival rate for primary teeth at 2 years. However, another systematic review compared multiple-surface ART to a "conventional approach," (i.e., composite or amalgam restoration), indicated the two types of treatment had similar survival rates (Raggio, Hesse et al. 2013). Data on the survival rate for multiple-surface ART in permanent teeth were inconclusive.

- **Silver Diamine Fluoride (SDF)** is a recently FDA-approved medicament for tooth hyper-sensitivity that is also used off-label as a caries arresting agent. SDF was developed as a tertiary preventive material, although primary preventive application has been recently suggested to promote healthy teeth (Oliveira, Rajendra et al. 2018). SDF is applied directly on the caries lesion, after drying, with a micro-brush. It is a safe, inexpensive, easy-to-apply material, with no need for caries removal. Therefore, it is a highly advantageous material for use in outreach programs in community settings or in rural areas with sub-optimal clinical environment. The main known disadvantage is the dark discoloration of de-mineralized tooth structure after application, which signals caries arrest. For this reason SDF is sometimes unacceptable to patients or their guardians, especially for use in the smile zone (Crystal, Janal et al. 2017). For this reason, a separate informed consent for SDF is suggested (Horst, Ellenikiotis et al. 2016). The most commonly used SDF solution is at 38% concentration, with 44,800ppm of fluoride.

In the most recent evidence-based clinical guidelines developed by the American Dental Association, biannual application of 38% SDF solution is the non-restorative treatment of choice in cavitated coronal lesions for both primary and permanent teeth (Slayton, Urquhart et al. 2018). In one systematic review, the overall proportion of caries arrest of SDF was 81% in primary teeth (Gao, Zhao et al. 2016). In a different meta-analytic review, SDF was also estimated to be 66% more effective in arresting caries compared with ART and fluoride varnish (Chibinski, Wambier et al. 2017). The effectiveness was even more dramatic compared with placebo, in which SDF was 154% more effective in arresting dental caries.

5. Dental Coverage, Access to Care and Utilization of Dental Services

a. Dental Expenditure

The estimated spending on dental care in the United Sates is 26.5 billion dollars among children aged 19 and younger, accounting for 11.4% of all health expenditure among children and adolescents (Bui, Dieleman et al. 2017). The same study ranked dental spending the 3rd most expensive care category in this age group, exceeding the spending on emergency care and prescribed pharmaceuticals. More than half of dental spending was toward check-ups and preventive services, which emphasizes the high cost of the traditional clinic-based provision of dental care and points to the need for a more cost-efficient models to provide preventive services. Furthermore, the fact that these funds were spent mostly on older children aged 10 and above highlights the missed opportunity for earlier prevention in a younger age, another challenge that might be addressed through alternative oral health delivery models.

b. Dental Insurance

Dental coverage is currently at an all-time high among children and adolescents, likely due to the Affordable Care Act enacted in 2010, which stated pediatric dental coverage as one of the 10 essential health benefits. Currently, nearly nine out of ten children have some sort of insurance coverage with dental benefits, a 10% increase from only 78.3% with dental coverage in 2000. Almost half of those currently covered are privately insured (Kamyar Nasseh and Marko Vujicic 2015). The number of children covered on public dental insurance (Medicaid and CHIP) increased from only 21% in 2000 to 38% in 2013 (Kamyar Nasseh and Marko Vujicic 2015).

c. Utilization of Dental Services

The increase in dental coverage, however, did not translate to a similar increase in use of dental services. Based on the latest report from Health Policy Institute, less than half of children aged 2-18 have visited a dentist at least once in the year of 2014 (Kamyar Nasseh and Marko Vujicic 2016). Since 2000, utilization increased only 5.4 points in dental services to 47.8% among children and adolescents in 2014. This low utilization of dental services, despite the expansion in dental benefits and coverage, could be explained by the shift toward public insurance with limited providers. It also suggests that dental coverage alone is not enough to guarantee access to care. Other potential barriers that could prevent seeking dental care are transportation, inconvenient appointment times, guardians' schedules, and level of health literacy.

6. Disparity of Dental Caries Incidence and Access to Care

a. Disparity of Dental Disease by Income and Race

The Surgeon General noted in the 2000 Oral Health in America report a "striking disparities" in dental disease by income (U.S. Department of Health and Human Services 2000). Since the Surgeon General address, the status of inequality in dental disease remained a challenge that has even worsened over the last two decades (Dye, Mitnik et al. 2017, Rozier, White et al. 2017). According to income level, the gap in the average dfs grew wider **(Figure 3.0)** from 4 times in 1988-1994 to 6.3 times in 2011-2012 between pre-school children living under 100% Federal Poverty Level (FPL) compared with counterparts living at ≥300% of FPL (Rozier, White et al. 2017). For 6-11-year-old children, the gap remained consistent over this time period for primary dentition (at 2.1) whereas the gap widened for the permanent dentition. The inequality gap also worsened among adolescents aged 12-17, from 1.4 times the average DMFS score between the same two poverty levels in 1988-1994, to 2.4 times the average in 2011-2012 (Rozier, White et al. 2017).

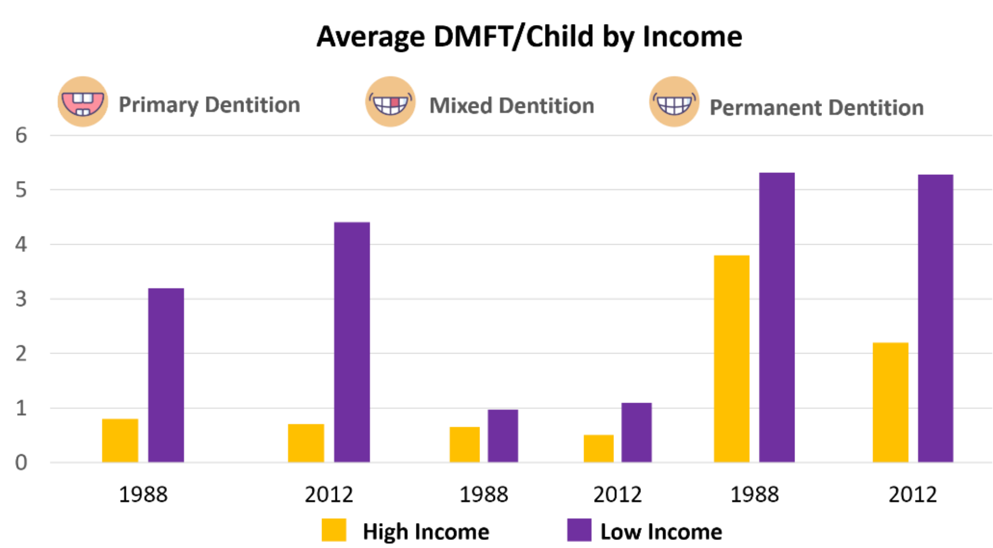


Figure 2.0: Income inequality in dental caries experience of U.S. children over two decades, by age group

ForsythKids School-based Dental Preventive Program

Compared with the conventional school-based dental programs described in the literature, which deliver only one or two interventions, ForsythKids is an unusually comprehensive preventive school-based dental program. Comprehensive school-based prevention is a promising approach to reduce barriers in access to oral health services where care is brought to the children with minimal disruption to their school schedule.

Previous analyses indicated promising evidence of effectiveness of school-based model and cost-effectiveness compared to traditional clinical-based delivery in the program evaluation span between 2004-2010 (Bukhari 2016). The results of this study will complement and expand on previous analyses to evaluate the outcomes of the program to shed light on the comprehensive model for dental caries prevention.

The aim of this thesis is to study trends in the risk of dental caries in ForsythKids participants. In addition, we aim to propose a new dental index to better measure preventive programs through preservation of health. We conducted a secondary data analysis of ForsythKids data from students ages 5-12-years between 2004-2010. The overall design of the study is a retrospective, open cohort. The data were originally collected for clinical purposes and extracted from patients' electronic dental records for analysis. Since the program was not designed as a research project, we lack a comparable non-exposed group. However, estimating the longitudinal trends using each child previous visit as a control period provides indirect evidence of program effectiveness.

ForsythKids

Chapter One: Comprehensive, School-Based Dentistry: Program Details and Baseline Students' Dental Health Indicators

Abstract

BACKGROUND: To describe the design, program details, and baseline demographics and oral health of participants in ForsythKids, a regional, comprehensive, school-based caries prevention program.

METHODS: We solicited all Massachusetts elementary schools with greater than 50% of students receiving free or reduced meals. Six schools initially elected to participate, ultimately followed by over 60 schools. Interventions were based on systematic reviews and randomized controlled caries prevention trials. Participating students received semiannual dental examinations, followed by comprehensive preventive care. Summary statistics regarding oral health indicators were derived from individual tooth- and surface-level data.

RESULTS: Over a six-year period, data were collected on 6,927 children. The number of students per school ranged from 58-681. The overall participation rate was 15%, ranging from 10% to 29%. Fifty-seven percent of the children were younger than 8 years at baseline. Approximately 54% of children experienced dental decay on any teeth at baseline; 32% had untreated decay on any tooth, 29% had untreated decay on primary teeth, and 10% untreated decay on permanent teeth.

CONCLUSIONS: Untreated dental decay was double the national average, even in schools within several blocks of community dental clinics. These data demonstrate the need for caries prevention beyond the traditional dental practice.

Introduction

In the U.S. in the early 2000s, 54% of elementary school children had experienced caries (untreated plus treated caries), and 29% had untreated caries (Steyerberg, Eijkemans et al. 1999). This has not markedly changed over the intervening years.(Control and Prevention 2019) Untreated dental caries (cavities) and dental pain among students are associated with lower academic performance and missing more school days.(Seirawan, Faust et al. 2012, Agaku, Olutola et al. 2015, Ruff, Senthi et al. 2019)

During this interim period, efforts were made to increase schoolchildren's access to dental services. The proportion of children who are covered with dental benefits is at an all-time high, with nine of ten children insured.(Kamyar Nasseh and Marko Vujicic 2016) In addition, Medicaid spending for children's oral health care increased more than 2.5-fold, reaching $5.3 billion by 2014.(U.S. Department of Health and Human Services) Yet the caries experience in the primary dentition has worsened in the last two decades, from an average of 4.0 decayed or filled surfaces ('dfs' for primary teeth; 'DFS' for permanent teeth) to 4.8 in 2014 among children aged 6-11 years.(Slade and Sanders 2018) During the same time period the average number of DFS in the permanent dentition remained unchanged, at 0.7 among the same age group, and the relative inequality in untreated caries increased from 21% to 26%.(Dye and Thornton-Evans 2010, Dye, Li et al. 2012, Capurro, Iafolla et al. 2015, Slade and Sanders 2018) Untreated caries prevalence in black, low-income, and Hispanic children is approximately 30%, higher than the current national average of 22%.(Dye, Mitnik et al. 2017, Slade and Sanders 2018)

The persistently high prevalence of caries experience suggests that access to preventive services does not meet current needs. To address the inadequacy of preventive care access, especially among the disadvantaged and highest-risk population, Healthy People 2020 objective OH-8 was to increase the proportion of low-income children and adolescents who received any preventive dental service during a year from 30.2% to 33.2% (Steyerberg, Eijkemans et al. 1999). Many strategies have been suggested to address this objective, including Medicaid expansion and the introduction of a new mid-level provider, the dental therapist. School-based care was recommended in more than 13 reports from U.S. federal agencies, national institutes, and organizations as a useful model for delivery of caries preventive measures.(Center for Health and Health Care in Schools 2012) Furthermore, the Healthy People initiative includes, as a goal, to increase the proportion of school-based health centers with an oral health component, as a means to increase access to caries prevention and reduce oral health disparities (US Department of Health Human Services and Office of Disease Prevention and Health Promotion 2010) (Steyerberg, Eijkemans et al. 1999).

In 2004, the Forsyth Institute began a school-based caries prevention program, ForsythKids, providing a range of preventive measures that had demonstrated efficacy in systematic reviews or human randomized control trials: glass ionomer sealants and interim therapeutic restorations, fluoride varnish, and fluoride toothpaste (Children's Dental Health Project 2014, Niederman, Feres et al. 2015, Culler, Kotelchuck et al. 2017, Slayton, Urquhart et al. 2018). Since that time, the number of school-based caries prevention programs has increased nationwide.(Children's Dental Health Project 2014, National Network for Oral Health Access 2014) Most programs offer only dental sealants, and many cover only specific teeth or specific ages. In contrast, we defined comprehensive as the simultaneous administration of the "best in class" preventive agents for topical fluoride (fluoride varnish) (Marinho, Higgins et al. 2002, Marinho, Higgins et al. 2002, Marinho, Higgins et al. 2003, Marinho 2008, Marinho 2009, Marinho, Worthington et al. 2013, ASTDD 2014), sealants (glass ionomer on all pits and fissures)(Griffin, Griffin et al. 2002, ASTDD 2003, Gooch, Griffin et al. 2009, Ahovuo-Saloranta, Forss et al. 2013, Community Preventive Services Task Force 2013, Mickenautsch and Yengopal 2013), interim therapeutic restorations, (glass ionomer on all asymptomatic carious lesions), (de Amorim, Leal et al. 2012, Frencken, Leal et al. 2012, Holmgren, Lo et al. 2013, Luengas-Quintero, Frencken et al. 2013) and fluoride toothpaste. ForsythKids is also comprehensive in a sense that it provides all-around dental care to schoolchildren of all ages, with three annual visits.

In this report, we describe the design, protocols, dissemination, and implementation of the ForsythKids program, which operates today in over 60 schools. We also present the demographic and baseline oral health characteristics of program participants, the latter of which documents the level of previously unmet need among schoolchildren entering the program.

Materials & Methods

Participants

***School selection and program implementation*.** In 2004 the Massachusetts Department of Health contacted all principals and nurses from Massachusetts Title 1 elementary schools to invite their participation in ForsythKids. In these schools over half the students qualify to receive free or reduced meals. In the spring of 2004, four elementary schools began participating, two in suburban -Essex county- and two in rural -Barnstable county-. Then, two elementary schools in urban -Suffolk county- joined the program in the following year. By 2007, the program served children from 30 schools in eastern Massachusetts and, by 2008-09, more than 60 schools. At the same time that schools were enrolled, we identified local community health centers and dentists interested in collaborating to provide continuing care.

Patient eligibility and enrolment. In the first year of the program, only children in grades K-3 were examined and treated. In subsequent years, all children in participating schools were eligible to enroll, if their guardians provided informed consent. The informed consent forms were written at an eighth-grade reading level, in multiple languages, as requested by schools. The sequence of distribution was from the investigators to school nurses to schoolteachers, to children, and finally, to parents, who then returned signed forms to teachers, to nurses, and finally back to the investigators. In all but the first year of the program, consent forms were distributed to parents with all other school forms at the beginning of the academic year. Schools or individual children could drop out of the clinical program at any time.

Instruments

Training, calibration, and standardization. To standardize examinations, dentists independently examined 10 students at baseline and discussed whether caries were present or not. Following this initial review, dentists were calibrated by independently examining another 10 students and comparing the results (kappa= 0.75).(Niederman, Gould et al. 2008) Dental hygienists delivered all services other than clinical oral exams. To standardize the delivery of care, prior to participating in the program, dental hygienists were trained to use Fuji IX glass ionomer in capsules (Frencken. and Holmgren. 1999). No hard tissue was removed. For subsequent visits after the initial school visits, dentists and hygienists were standardized but not calibrated.

Oral examination. Dentists clinically examined children following guidelines provided by the National Institute of Dental and Craniofacial Research.(1991) The examining dentist dried tooth surfaces with gauze squares and performed visual-tactile full-mouth oral examinations with the aid of halogen lights, disposable mirrors, and explorers. Full-mouth examinations included: examination of all teeth and surfaces as to whether they were decayed, missing, filled, sound, or exhibiting pulpal involvement. The exam also included an assessment of pain, swelling, infection, abscess, presence of occlusion, or oral pathology. Data from clinical exams were recorded on electronically readable paper forms, which were scanned and uploaded to the data coordinating center.

Procedures

Consenting program participants were eligible to receive triannual preventive visits: two dental examinations and treatment planning by a dentist at the beginning and the end of each academic year, three follow-on preventive care provided by a dental hygienist **(Figure 1.1)**. Services provided at each visit included: (i) Prophylaxis with a disposable rubber cup (Denticator, Earth City, Mo.) and chair-side oral hygiene instruction; (ii) Placement of glass ionomer sealants on all teeth with pits or fissures, with replacement if needed (Fuji IX, GC America, Alsip, Ill.); and (iii) placement of interim therapeutic restorations (also called: therapeutic sealants, atraumatic restorative treatment, temporary fillings) on all asymptomatic carious lesions (Fuji IX, GC America, Alsip, Ill.). The preventive and therapeutic sealants used in the study were glass ionomer except in 2007, when sealants were light-cured resin based (Embrace, Pulpdent, Watertown, MA) and no therapeutic sealants were placed. This one-year change was made at the request of the Massachusetts Department of Health. Following placement of glass ionomer sealants and interim therapeutic restorations we (iv) provided toothbrushes (Henry Schein, Melville, N.Y.) and toothpastes (Big Red, Colgate-Palmolive Company, New York City); and (v) applied fluoride varnish (Duraphat Colgate Pharmaceuticals, Canton, Mass., or Cavity Shield, OMNII Oral Pharmaceuticals, West Palm Beach, Fla.). In the presence of symptomatic teeth (mobility, swelling, pain, or fistula), the program's patient advocate followed up by phone to ensure adequate care is received.

Examination and care reports were prepared at the time of care and given to children in their native language and to the school nurse. Recommendations for treatment were also provided, and parents were given referrals to local dentists or health centers for further treatment. Any instances of emergency care were reported to the school nurse and the child's parent, and the local school's protocol was followed.

Data Analysis

We used the baseline data extracted from the clinical records of ForsythKids participants since its inception in 2004 to December 2010. Analysis was restricted to children ages 5-12 years. We excluded data from schools with fewer than 50 total students over the entire period.

Oral health indicators were calculated and reported separately for permanent teeth, primary teeth, and for both dentitions. These indicators included the proportion of children with: 1) caries experience (i.e., caries or restorations), 2) untreated carious surfaces, 3) restored cavities, 4) fissure sealants in posterior teeth (as a proxy for previous preventive care), 5) either treated dentition or fissure sealants (a proxy for any previous dental care, whether preventive or otherwise). We also calculated 6) the mean number of DFS & dfs(Cappelli. and Mobley. 2007), and 7) the significant caries index (SiC), which is the mean DFS or dfs score for patients with scores in the highest tertile.(M., Bratthall et al. 2001)

We calculated descriptive statistics for demographics and oral health measures separately for participants in the first six and remaining schools and stratifying by the community water fluoridation (CWF) status of the school area.

Results

Over a six-year period, data were collected on 6,927 children, of whom 37% were in the first six schools. In total, there were 33 schools included: two urban, and 14 suburban schools, all of which were in communities with water fluoridation (CWF). The remaining 17 schools were located in rural communities without CWF. The number of students per school ranged from 58-681. The overall participation rate was approximately 15%, ranging from 10% to 29% **(Table 1.1)**. Approximately 48% of participants were female, with a mean age at entry of 7.4 years (standard deviation ± 1.7 years). Three-quarters were 8 years or younger at baseline, a proportion that was slightly higher in the first six schools and lower in the remaining schools. Only 31% of participants reported race/ethnicity **(Table 2.1)**. Among these, close to half were reported as being Black, Asian, or more than one race.

Approximately 54% of children had untreated or treated dental decay (caries experience) at baseline; 32% had untreated decay on any tooth, 29% had untreated decay on primary teeth, and 10% untreated decay on permanent teeth **(Table 3.1)**. These percentages were higher in students attending school in areas with CWF. Similarly, 38% of students had at least one restoration, a percentage that was higher in schools with CWF than in schools without CWF. Approximately 36% and 57% had evidence of previous preventive care or history of treated dentition, respectively (range over schools: 22%-60% and 36%-73%, respectively). The proportion of children with at least one sealed permanent tooth was 38% (range: 23%-65%).

As measures of disease intensity in the primary teeth, the mean dft and SiC were 1.9 (range 0.6 to 2.5) and 5.0 (range 3.7 to 5.8), respectively, across all schools. For the permanent teeth, the mean DFT and SiC were 0.4 (range 0.03 to 0.75) and 1.3 (range 0.1 to 1.7), respectively (**Table 3.1**).

Discussion

Among children attending the ForsythKids school-based caries prevention program, at their initial visit, approximately one-third had untreated caries, and nearly two-thirds had no evident history of preventive sealants on permanent dentition. This is despite the fact that 57% of the children had received prior dental care. It is clear from these and national statistics that traditional clinical-based delivery of dental care is failing many children. As we discuss below in more detail, by bringing care directly to children, school-based prevention programs address many of the barriers' children face in accessing dental care. Compared with the vast majority of school-based dental programs described in the literature, which deliver only one or two interventions, ForsythKids is a comprehensive preventive school-based dental program. It is much closer to the standard of care offered in dental clinics and costs a fraction of clinic-based care on a per-patient, per-visit basis. This approach to care is cost-saving and cost effective when compared to both no intervention and traditional sealant programs.(Huang, Ruff et al. 2019)

The schools included in this analysis were located in urban and suburban areas with CWF and rural areas without CWF, so we presented results stratified by this factor. The results may appear counterintuitive in that average oral health was worse in the schools with access to CWF than in those without CWF. This study was not designed to assess the effectiveness of CWF, and the results should not be interpreted as contradicting that effectiveness, as the school populations likely vary in many other ways. In particular, we had little information about students' individual-level oral health risk factors. Among all participating children, only 31%

provided information about their race. We do not know whether the sample is representative of each town's or school's racial distribution. And, although a large proportion of children attending the participating schools were from economically disadvantaged households (U.S. Department of Education, Institute of Educational Sciences et al.), we did not have household income information for individual program participants.

Other school-based oral health programs operate in the Boston area. One such school-based sealant program serving low-income families in an urban community north of Boston reported that in 2006-2007, 35% of schoolchildren in kindergarten, 3rd, and 6th grade presented with untreated caries (Culler, Kotelchuck et al. 2017). In both that report and among ForsythKids participants, the prevalence of untreated caries was more than double the Massachusetts state average of 16.7% among students of similar grade during the same period,(B;, M; et al. 2008) and nearly double the national prevalence of caries at that time.(Dye, Li et al. 2012)

The results we report here demonstrate that high-risk children living within blocks of a health center that accepts Medicaid have unmet needs. This suggests that outreach programs are needed, even in the absence of the typical financial and non-financial barriers to dental care. Specifically, all of the first six schools were located within one to eight blocks of a federally qualified community health center or dental school that accepts Medicaid. Thus, increasing geographic access and affordable health care does not in itself reduce disparities in oral health among high-risk children. It is therefore likely that parents' beliefs, cultural or social norms about dental care, and language also present barriers to oral health care for children.(Mofidi, Rozier et al. 2002, U.S. Department of Health and Human Services 2011, Badri, Saltaji et al. 2014)

In a national survey, financial barriers were the main reported reason for not obtaining dental care when needed among children and adolescents.(Vujicic; 2019) Other non-financial barriers reported were guardians' perceived lack of need, being too busy, children's anxiety, lack of access to a suitable dental office, workday hours, or distance.(Vujicic; 2019) Parents have also reported missing an average 2.5 days/year from work because of their children's dental problems.(Seirawan, Faust et al. 2012) In another national survey that included all health services, dental care was reported to have the highest unmet need among children, with cost of care most frequently cited as a barrier.(Vujicic, Buchmueller et al. 2016)

School-based prevention can circumvent these barriers by bringing effective care directly to children, potentially reducing cost of care delivery and inequalities stemming from socioeconomic barriers or cultural norms.(Community Preventive Services Task Force 2013, Ran, Chattopadhyay et al. 2016) Both the Centers for Disease Control and Prevention and the American Dental Association support school-based prevention.(Gooch, Griffin et al. 2009) However, school-based prevention can be effective only if children enroll and participate in the program, and low participation may be the largest challenge facing school-based prevention programs.(Dillman Carpentier, Mauricio et al. 2007, Galea and Tracy 2007, Bruzzese, Gallagher et al. 2009, Detty 2013)

In the ForsythKids program, distributing consent forms along with other school documents at the beginning of the academic year likely increased informed consent rates. However, the average overall participation rate in ForsythKids was low at 15% of eligible students, ranging between 10%-30% per grade. Traditional active consent, through which parents must sign a form to “opt in” to programs, results in multiple opportunities for omission, such as misplaced forms, even among parents who may be interested in the program.(Carroll, Choi et al. 2009, Ohio Department of Health 2012) Directors of school-based dental programs have attributed the low participation rate to the failure of obtaining consent, with average enrollment between 25%-50% of students.(National Network for Oral Health Access 2014) Alternative approaches to consent may be more effective in increasing participation rates, especially passive consent, in which all children are included by default unless their parents refuse care (i.e., “opt out”).(Johnson and Goldstein 2003, Abadie and Gay 2006).

It is possible that some parents do not consent because they believe that their children do not need the services offered, perhaps because they already receive preventive dental care outside of schools. Yet 56% of children who had evidence of previous dental care also had untreated caries or lacked sealants, suggesting that those attending dental offices were not getting adequate preventive care. It is likely that the nonparticipants—children not seen in the ForsythKids program—may have even greater need than those who participated. Reaching children at the highest risk of untreated decay would yield the greatest efficacy and cost-effectiveness.

Conclusions

School-based care presents an opportunity to reach a large number of underserved children and bypasses many of the barriers they face in accessing care. Because care is concentrated where children already spend their time, school-based prevention can be delivered efficiently and cost-effectively.(Griffin, Naavaal et al. 2016, Huang, Ruff et al. 2019) School-based prevention could thus be a key tool to reach and maintain Oral Health 2020 goals.

Implications for School Health

Unmet dental need and toothaches are associated with school absenteeism (Agaku, Olutola et al. 2015). In addition, children who report dental pain within six months have lower average GPA and are less likely to complete their homework compared with children who do not experience dental problems within the same time.(Guarnizo-Herreno and Wehby 2012, Seirawan, Faust et al. 2012, Ruff, Senthi et al. 2019) Students with dental problems are also more likely to be shy and to report feeling worthless, unhappy, or less friendly.(Guarnizo-Herreno and Wehby 2012) Dental caries disproportionally affects vulnerable racial minorities and low-income groups: the prevalence of untreated caries among African-American children is 1.5 times the prevalence among non-Hispanic Whites, and children living with families below 100% of the federal poverty level have 2.7 times the prevalence of untreated caries compared to their peers living with families 300% or above the federal poverty level.(Fleming and Afful 2018) This is, in part, because they are more likely to face barriers to accessing dental care, including cost, their parents' work schedules, and parents' oral health illiteracy. Oral health care delivered to children in schools overcome many of these critical barriers.

There is ample support for the school-based model of care delivery, specifically for dental sealant programs. Such programs lower cost, improve access, and prevent dental disease. Therefore, in areas where mobile dental health programs are available, schools should partner with them to ensure equitable access to dental care to all students. Here, we demonstrate the need for such care in children attending Title I schools in the Boston area, even when children's public schools were within several blocks of a community dental clinic where they could access care. We also described details regarding the ForsythKids clinical program, which differentiates from sealant programs in offering comprehensive care more similar to that received in private practice and community dental clinics. Costs are billed to children's insurers, either private insurance or Medicaid. In areas where mobile dental health programs are not already available, the program details provided here can enable schools to partner with local community health centers, dental schools, or businesses to establish oral health care delivered to their students on the school premises.

Figure 1.1: Procedural Workflow in the ForsythKids Comprehensive, School-Based Oral Health Prevention Program

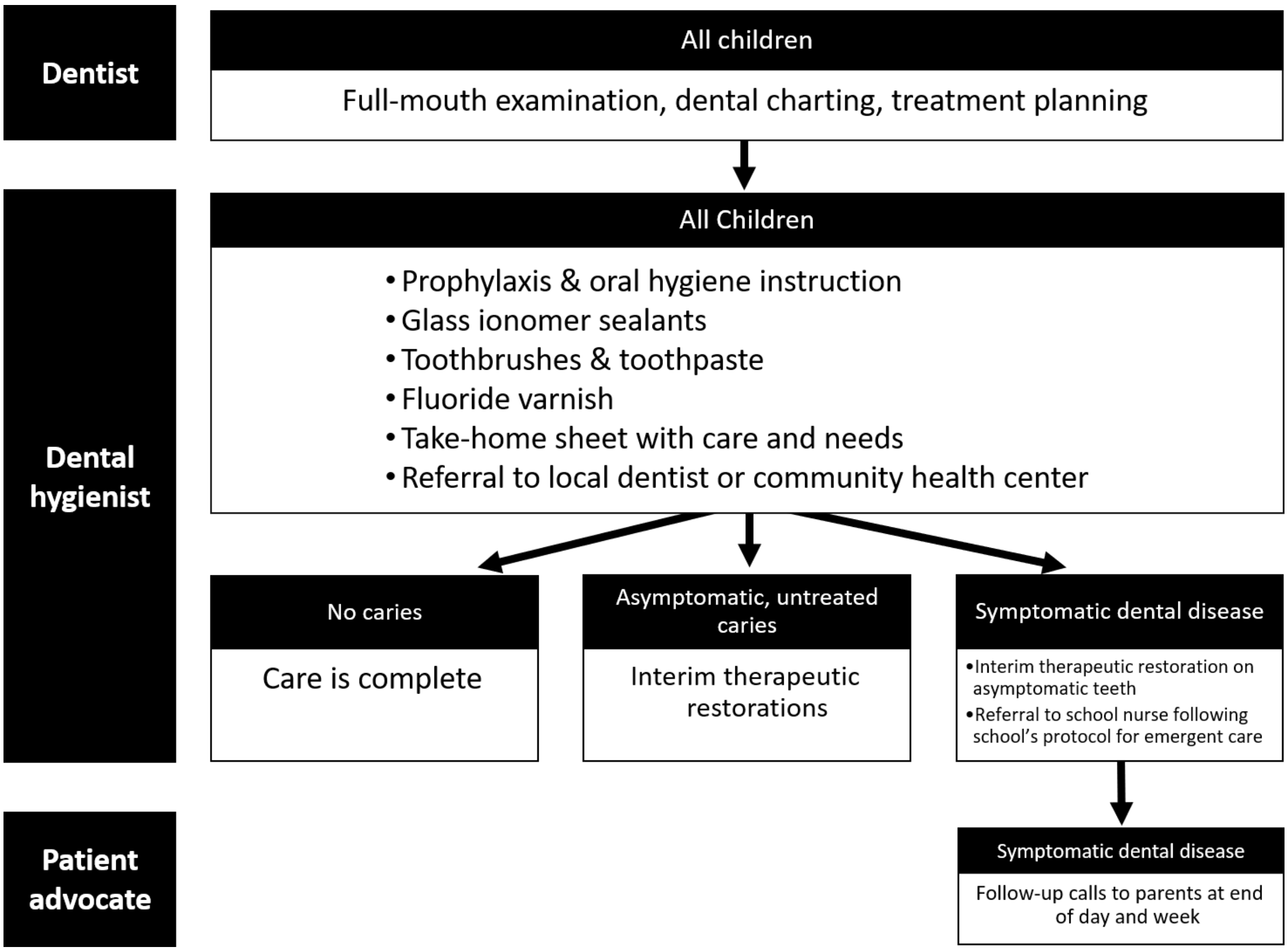


Table 1.1: Proportion of Students Participating in ForsythKids School-Based Oral Health Prevention Program, by Grade (2004-2010)

Visit Year	Age at Entry							
	5	6	7	8	9	10	11 or 12	Total
	No.	No.	No.	No.	No.	No.	No.	No.
2004	9	136	189	175	100	38	18	665
2005	4	120	141	112	64	8	2	451
2006	5	78	53	50	14	10	2	212
2007	237	343	289	249	216	139	61	1,534[a]
2008	312	360	350	309	257	174	122	1,884
2009	355	417	275	213	187	141	100	1,688
2010	74	125	71	61	71	45	46	493[b]
Total enrolled in that grade in the ForsythKids	996	1,579	1,368	1,169	909	555	351	6,927
Total enrolled in that grade in the 33 schools*	7,339	8,594	8,989	8,174	6,698	5,707	1,204	46,705
Estimated participation Rate (%)	14%	18%	15%	14%	14%	10%	29%	15%

*Data Source: U.S. Department of Education, National Center for Education Statistics, Common Core of Data (CCD), "Public Elementary/Secondary School Universe Survey", 2003-04 v.1a, 2004-05 v.1b, 2005-06 v.1a, 2006-07 v.1c, 2007-08 v.1b, 2008-09 v.1b, 2009-10 v.2a, 2012-13 v.1a.

[a]The increase of total number of the program participants in 2007 mainly explained by the expansion of ForsythKids that year beyond the first 6 sites, to include 20 more schools.

[b]Between 2009-10, former staff members left and started their own dental public health program, taking some sites with them, explaining the drop-in sites and enrollment in 2010 data.

Table 2.1: Demographic Characteristics of Students Participating in the ForsythKids School-Based Oral Health Prevention Program at Entry, 2004-2010

Characteristic	All Participants		First six schools		Remaining schools	
	No.	%	No.	%	No.	%
Total	6,927	100	2,588	37	4,339	63
Gender						
Male	3,496	51	1,271	50	2,225	52
Female	3,338	48	1,286	50	2052	48
Missing	93	1	31	1	62	1
Race						
Reported Race (n=2,160):						
Black/African American	393	18	172	35	221	13
White	1,209	56	173	35	1,036	62
AI/AN/Hawaiian/PI*	50	2	9	2	41	2
Asian	230	11	56	11	174	10
More than one race	278	13	81	17	197	12
Did not report race	4,767	69	2,097	81	2,670	62
Age at Entry						
5	996	14	254	10	742	17
6	1,579	23	669	26	910	21
7	1,368	20	624	24	744	17
8	1,169	17	50	19	668	15
9	909	13	335	13	574	13
10	555	8	130	5	425	10
11 or 12	351	5	75	3	276	6

*AI: American Indians, AN: Alaskan natives, PI: Pacific Islanders

Table 3.1: Baseline Oral Health and Dental Care Indicators Among Participants in ForsythKids School-Based Oral Health Prevention Program, 2004-2010

Dental Health Indicators	Total		First six schools				Remaining 27 schools			
			CWF* (4 schools)		No CWF* (2 schools)		CWF* (12 schools)		No CWF* (15 schools)	
	N	%	N	%	N	%	N	%	N	%
Total	6,927	100	1,935	28	653	9	2,273	33	2,066	30
Caries experience	3,763	54	1,170	31	420	11	1,319	35	854	23
(any carious or restored teeth)										
Caries experience in permanent teeth	1,190	19	499	42	167	14	356	30	168	14
Caries experience in primary teeth	3,448	52	1,061	31	378	11	1,221	35	788	23
Untreated caries	2,211	32	695	31	326	15	620	28	570	26
(any carious, not-restored teeth)										
Untreated caries in permanent teeth	623	10	294	47	133	21	105	17	91	15
Untreated caries in primary teeth	1,955	29	587	30	274	14	573	29	521	27
Restored teeth	2,646	38	835	31	254	10	1,028	39	529	20
(any restored teeth)										
Restored permanent teeth	724	12	297	41	59	8	277	38	91	13
Restored primary teeth	2,423	37	760	31	234	10	946	40	483	20
Sealants in any posterior teeth	2,481	36	602	24	221	9	916	37	742	30
Sealants in permanent posterior teeth	1,806	38[#]	448	25	177	10	652	36	529	29
Sealants in primary posterior teeth	1,167	18[$]	254	22	94	8	493	42	326	28
Previous care	3,952	57	1.120	28	351	9	1.468	37	1.013	26
(any restoration or sealant)										
Previous care in permanent teeth	2,187	36	647	30	198	9	776	35	566	26
Previous care in primary teeth	3,112	47	904	29	282	9	1,224	39	702	23
Mean DFT[a]	0.4		0.7		0.6		0.4		0.2	
Mean SiC[b] (permanent teeth)	1.3		1.6		1.4		1.1		0.6	
Mean dft[c]	1.9		2.1		2.3		2.2		1.3	

Mean SiC (deciduous teeth)	5.0	4.8	4.9	5.1	4.9

*CWF: Community water fluoridation

[#]Among children with at least 1 permanent posterior tooth

[$]Among children with at least 1 primary posterior tooth

[a]DFT: Decayed and filled teeth for permanent dentition

[b]SiC: Significant caries index

[c]dft: Decayed and filled teeth for primary dentition

Chapter Two: Longitudinal Analysis of New Caries Experience in a School-based Prevention Program, ForsythKids

Abstract

Objective: To evaluate how fast dental caries is developing over time among a cohort of children participating in ForsythKids, a comprehensive school-based dental prevention program in greater Boston area.

Methods: We analyzed ForsythKids data between 2004-2010 for n=5,307 children aged 5-12 years. We fitted negative binomial regression models using the generalized estimating equations framework with exchangeable correlation to estimate the incidence rate ratio (IRR) of developing new dental events (untreated caries or restoration) with each additional preventive visit. Estimates were reported for all children and stratified by baseline dental health status, as well as for the whole dentition and each dentition separately (primary and permanent). In addition, time to the first dental event was calculated. Using Cox regression models, we estimated the risk of developing the first dental event among children who had caries experience compared to those who were caries-free at baseline.

Results: The average number of preventive visits for ForsythKids children was 3.14 visits, with a median of 1 year of follow up. Overall, each additional visit was associated with an 8% reduction in new dental events (95%CI= 5%, 10%). Children with caries experience at baseline observed a higher reduction of new dental events (10%; 95%CI=13%, 7%) than caries-free children. While ForsythKids demonstrated a reduction of new events in primary dentition (28%; 95%CI=31%, 25%), there was an increase in permanent dentition (15%; 95%CI=12%, 19%). The

risk of developing the first event was 145% higher among children with caries experience (95%CI= 124%, 167%) compared to children with no previous caries experience.

Conclusions: Each additional preventive visit in ForsythKids was associated with an overall reduction in development of new events, especially among high-risk children with caries experience. However, permanent dentition had increased number of events through the increased number of restorations.

Introduction

Dental coverage is currently at an all-time high among children and adolescents in the United States (US).Nearly nine out of ten children have some sort of insurance coverage with dental benefits, an increase from only 78.3% with dental coverage in 2000 (Kamyar Nasseh and Marko Vujicic 2015). In addition, dental care spending among children and adolescents is at record high with $27 billion, accounting for 11.6% of all health expenditure (Bui, Dieleman et al. 2017, Manski and Rohde 2017). Dental care ranked the 3rd most expensive care category in this age group, exceeding the expenditure on emergency care and prescribed pharmaceuticals (Bui, Dieleman et al. 2017).

Nevertheless, dental caries remains a significant public health problem among children and adolescents in the US. Despite the great advancements in dental technologies in the last 20 years, the caries experience (both treated and untreated dental diseases) has not improved since the early 2000s. Among school-age children, the average decayed or filled surfaces (‘dfs’ for primary teeth; ‘DFS’ for permanent teeth) increased from 4.0 in primary dentition to 4.8 in 2014, and the average number of DFS in the permanent dentition remained unchanged at 0.7 teeth (Slade and Sanders 2018). Caries disproportionally affects children from low-income families, and the gap has widened over time (Dye and Thornton-Evans 2010, Dye, Li et al. 2012, Capurro, Iafolla et al. 2015, Rozier, White et al. 2017).

The reduction in untreated caries observed in the early 2000’s among children and adolescents can be partially explained by improved access to dental treatment provided by the Children's Health Insurance Program (CHIP) when signed into law in 1997 (Manski, Moeller et al. 2001, Kamyar Nasseh and Marko Vujicic 2016). However, added insurance did not necessarily reduce the incidence of the disease nor promoted health. In addition, the Affordable Care Act (ACA) made dental coverage an essential health benefit among children and adolescents (United States 2010). This increase in dental coverage was not followed by a proportional increase in use of dental services, especially preventive care, which can arrest the disease at early stages without the need of restorative care. As of 2015, more than half of U.S. children had not visited a dentist within the previous year, indicating other factors likely influence accessibility to care (Kamyar Nasseh and Marko Vujicic 2016). Such factors include parental oral health illiteracy, their work schedules, remoteness to dental providers, and cost (United States. Department of Health and Human Services. and National Institute of Dental and Craniofacial Research (U.S.) 2000).

Increased spending on dental care and expansion of dental coverage have not translated to preservation of dental health. The high cost of traditional clinical care, underutilization of care and stagnant caries experience demand innovative and cost-effective approaches to tackle these challenges. Tele-dentistry, introduction of a new mid-level providers into the dental workforce (dental therapists), amending supervision requirements of the existing dental hygienists, and providing care to children at school are some of the suggested methods to lower cost and improve access to dental care (American Public Health Association 2006, Daniel, Wu et al. 2013, Friedman and Mathu-Muju 2014, Johnson, Serban et al. 2017).

Comprehensive school-based preventive care is a promising cost-effective approach to reduce barriers in access to care (Bukhari 2016). School-based model of care delivery is proven effective and recommended method to bring preventive measures to children. Increasing the use of school-based oral health care was incorporated as one of the objectives of Healthy People 2020 (Center for Health and Health Care in Schools 2012, HHS 2014, Griffin, Naavaal et al. 2017). Unlike conventional school-based dental programs, which deliver only one or two interventions, ForsythKids delivers comprehensive dental care that closely resembles traditional clinic-based care. However, no prior study has examined the preventive effect of such model to maintain dental health over time. So, the primary aim of this study is to evaluate the longitudinal caries experience among children participating in ForsythKids, by reporting the incidence rate (IR) of new dental events, defined as new untreated caries or restoration on previously sound tooth, at each post-baseline preventive visit, as well as the incidence rate ratio (IRR) of new dental events over time. The secondary aims is to calculate the survival time to the first dental event, as a measure of the program effectiveness to keep children caries-free, and to estimate the hazard ratio (HR) between high-risk children who had caries experience compared to those who were caries-free at baseline.

Materials & Methods

We conducted a secondary data analysis of ForsythKids school-based dental preventive program from students ages 5-12-years between 2004-2010 in greater Boston area. The cohort was followed retrospectively from their first exposure to preventive care (baseline visit) to estimate IR of new dental events at each visit, IRR compared to the previous visit, survival time to first dental event, and HR of survival without new dental event among children who had caries experience compared to those who were caries-free at baseline. The data was originally collected for clinical purposes, and it was extracted from patients' electronic dental records for the analysis.

ForsythKids Program Description:

School Eligibility and Recruitment: Schools in the greater Boston area were eligible to join ForsythKids program if they were under Massachusetts Title I of the federal Elementary and Secondary Education Act, with more than 50% children receiving federal free and reduced-cost meals programs. The ForsythKids program started providing services in 2004 to school-children in grade 1-3 at six elementary schools. Subsequently, the program expanded to nearly 60 locations and included more older schoolchildren, preschoolers, and adults.

Institutional Review and Patient Eligibility and Recruitment: ForsythKids received its first IRB approval to start the clinical program in in July 2003. All children who attended a participating school were eligible to receive preventive services. At the beginning of each academic year, children were given consent forms, along with all other school forms, to be signed by their guardian to participate in the ForsythKids clinical program. Schools or individual children could drop out of the clinical program at any time.

Clinical Interventions: Portable clinics were used in each school site to deliver care. All children participating in ForsythKids were eligible to receive three annual visits as described below Dentists were calibrated at the beginning of every school year according to National Institute of Dental and Craniofacial Research diagnostic criteria for dental caries (Epidemiology and Oral Disease Prevention Program. National Institute of Dental Research 1991). Throughout the years, different preventive procedures were added, changed, or eliminated to provide the best evidence-based practice and to follow the requests of the Massachusetts Department of Health.

In the first visit at the beginning of each school year, a full dental examination for each child was performed by a dentist. Calibrated dental hygienists then provided dental prophylaxis, oral hygiene instruction and kit (toothbrush and fluoridated toothpaste) and applied fluoride varnish at each visit. Pits and Fissure Sealants (PFS) were placed or replaced, according to the treatment plan determined by the dentist, over the pits and fissures of all posterior permanent molars. Over the years of the program, ForsythKids moved from glass-ionomer-based sealants to resin-based sealants. Atraumatic restorative treatment (ART, also called: therapeutic sealants, interim therapeutic restorations, temporary fillings) were provided to control for asymptomatic active decay.

In the mid-year visit, dental hygienists provided prophylaxis again, re-applied fluoride varnish, and applied PFS if needed. The third annual school visit occurred at the end of the academic year to follow through on treatment plans, to provide cleaning, and to apply fluoride varnish. Following each visit, guardians were provided with a written report, in their native language, regarding the clinical exam, services received, recommendations, and referrals to community health centers and collaborating dentists in case of active disease. In the presence of symptomatic teeth (mobility, swelling, pain, or fistula), the program's patient advocate followed up by phone to ensure adequate care was received.

Data Analysis:

Inclusion and Exclusion Criteria: Data analysis was restricted to children between the age of 5-12-year-old, to capture the whole mixed dentition period for both primary and permanent teeth. Children included in the analysis should have at least one follow-up visit after receiving the first preventive measures, and data were excluded for children who cannot be linked to a baseline visit. We limited the analysis within five post-baseline follow-up visits for IR and IRR estimations, and 3 years of follow-up for HR survival analysis, due to scarcity of data beyond which it will undermine our estimates. We also excluded data from schools with fewer than 80 students participating in the program over the program period, had fewer than four Forsythkids visits in total, or had fewer than two visits annually. But we retained visits for students seen at an eligible school at any point in their history, even if those visits occurred at an otherwise excluded school.

Defining Exposure, Outcome and Time Metric: ForsythKids is an open cohort, in that schools and children can join and leave at different times, called entry and exit times, respectively **(Figure 1.2)**. For this longitudinal analysis, the independent variable of interest was number of preventive visits **(Figure 2.2)**. The first examination visit for each child established their own baseline to count the number of post-baseline preventive visits received. Preventive visits were measured as a discrete count, defined as receiving prophy cleaning, fluoride varnish, PFS application, or any combination thereof.

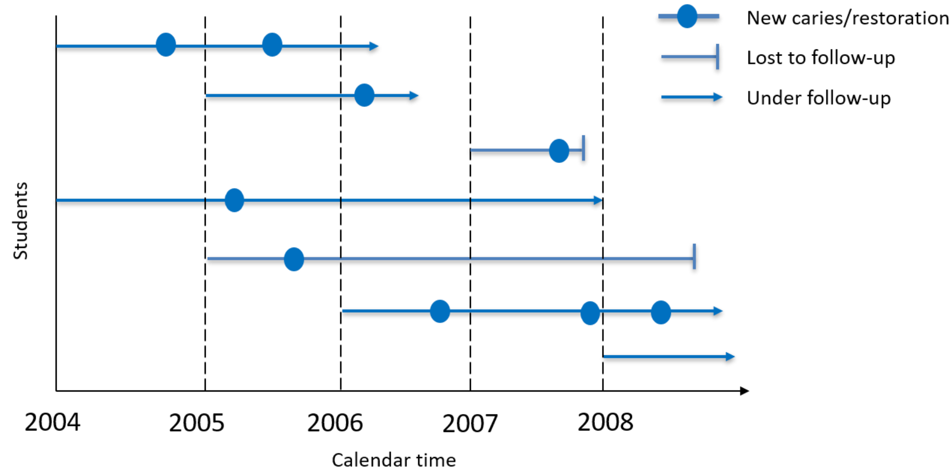


Figure 1.2: ForsythKids cohort entry/exit points, follow-up and outcome development

The time elapsed between visits was calculated and summed over all post-baseline visits to derive the person-time contributed to the study. The time metric used in our analysis was "days since last visit,". Time of entry (t_0) for each child is the baseline visit, and time was measured in discrete periods between preventive visits in person-days at each visit k**:** $\Delta t_k = \sum(t_k - t_{k-1})$ **(Figure 2.2)**. The outcome was be recorded at each preventive visit, starting at the first visit after baseline, to evaluate the exposure of k-1 visits with Δt_k person-time at risk. Risk sets were created at each level of exposure (i.e., each number of preventive visits).

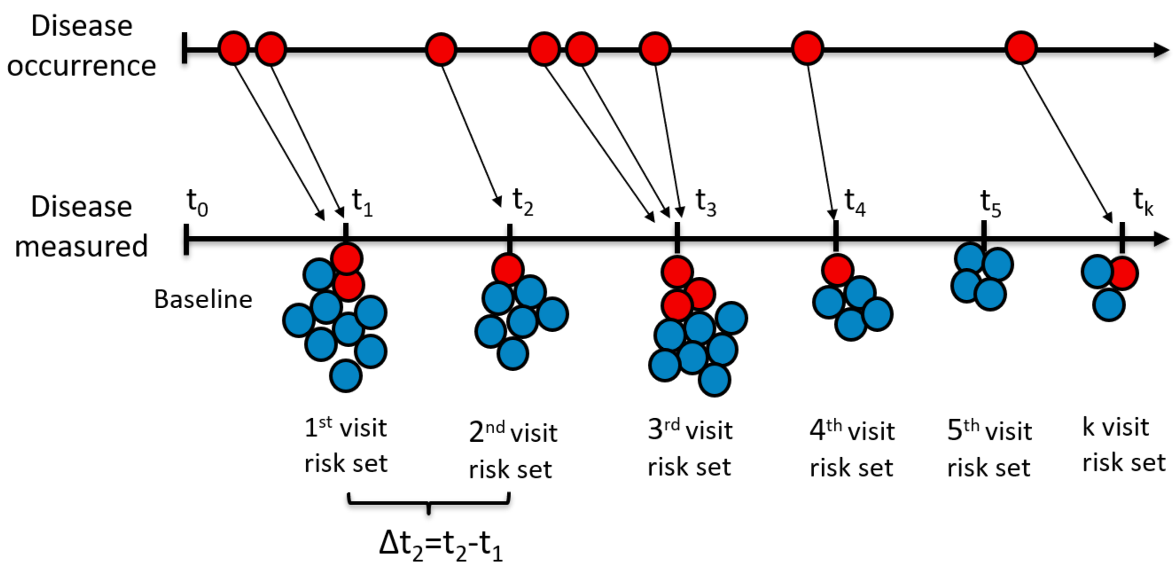


Figure 2.2: The difference between how the outcome (new dental events) occurs in the real continuous time (top line) compared to how it's measured in ForsythKids (bottom line). At each post-baseline preventive visit, we counted the number of new dental events, created a corresponding risk set, then summed the person-days contributed by all students in each risk set

The outcome of interest was the count of new dental events, defined as a new untreated caries or a new restoration on a previously sound tooth. Each child could develop a maximum of 28 new events in the permanent dentition (excluding third molars), and 20 new events for the primary teeth. Interproximal restorations, especially in permanent teeth, would help indicate a previous non-clinically visible caries. Due to the difficulty of distinguishing tooth-color restorations, some surfaces were recorded as carious or filled in k-1 visit and then sound at visit k. In the case of such apparent logical discrepancies, we re-coded the surface as filled. Extracted teeth were not recorded as an event. We assumed missing primary teeth were due to natural exfoliation, whereas extraction of permanent teeth due to caries is unlikely in this age group. We stratified the population, based on their baseline dental health, to children with previous caries experience (high-risk) and caries-free children (low-risk), and low-risk children.

Measures of outcome were calculated for each dentition separately (primary and permanent), and for the whole dentition.

Each child's observation was censored at the end of the study period (December, 2010) or when treatment ended for various reasons, including: 1) the child moved out of the school; 2) the child did not provide the annual consent; 2) the school opted out of the program; 3) or the child moved to seventh grade (administrative censoring). Observations for specific teeth could be censored if a tooth became missing.

Statistical Analysis: First we described the characteristics of ForsythKids population at baseline, reporting frequencies and percentages for categorical variables, and averages with standard deviations (SD) for continuous variables. To account for individual clustering of new dental event over visits, we used Generalized Estimating Equations (GEE) with exchangeable correlation. Using the GEE framework, we fitted negative binomial regression models, with the natural logarithm (ln) of person-days as an offset, to estimate the IRR for of new dental events associated with each additional preventive visit. We also report the IR of new dental events per 1000 person-days at each of the five post-baseline visits.

For the survival analysis, we established the baseline visit as the time of entry and time of origin. The maximum possible duration of follow-up time was 3 years. We fit Cox proportional hazards regression models, after testing for the proportional hazard assumption, to estimate the HR of the first dental event among children with caries experience compared to caries-free children at baseline. Efron's method was used to handle tied failure times.

We estimated the overall IR at each visit, survival time to first dental event, the average IRR and HR of new dental events with each additional visit and its respective 95% confidence intervals (95%CI). Estimates were reported for the whole dentition, and for each dentition separately (primary and permanent). In addition, we reported IR and IRR estimates stratified by the presence of dental disease at baseline. In secondary analysis, we estimated the IR and IRR associated with visit number for new untreated caries and new restorations separately. All the data analyses were carried out by using StataSE 15.1 (StataCorp, College Station, Texas).

Results

Out of 6,927 ForsythKids participants, 5,307 children had at least one post-baseline follow-up visit, with an average of 3.14 preventive visits (SD ± 1.45 visits) **(Table 1.2)**. Half of the children were male, and 33% reported race, with the majority being non-Hispanic whites (54%). More than half of the children (54%) had experienced dental caries before joining ForsythKids. The average dfs at baseline was 1.9 teeth (SD ± 2.5 teeth), affecting 50% of the children with primary teeth. Average DFS was 0.4 tooth (SD ± 0.9 tooth) among the 16% of ForsythKids patients who had any permanent teeth. Over the 7 years of follow-up between 2004-2010, the average time spent in the program was 1.24 years (SD ± 0.96 year), and the median time was 1 year.

The observed average incidence was 4.13 events/1000 person-days in the first visit after baseline (95%CI=3.96, 4.30), which decreased to 3.26 events/1000 person-days (95%CI=2.77, 3.74) by the fifth preventive visit **(Table 2.2, Figure 3.2)**. This trend was confined to the primary teeth, and the incidence increased in the permanent teeth. However, when untreated caries and new restorations were treated as two different types of events, the incidence of untreated caries decreased with each additional preventive visit in primary, permanent and both dentitions together. But new restorations increased in permanent dentition over time **(Figure 4.2, Figure 5.2)**.

Compared with children who were caries-free at baseline, children with any previous caries experience had a steeper decline in incidence of new dental events with each additional preventive visit. The difference in incidence rates was observed in analyses limited to the primary dentition and in analyses of the combined dentitions **(Table 3.2, Figure 3.2)**. Permanent dentition, however, showed an increased IR of new dental events and new restorations, especially among caries-free children at baseline **(Figure 5.2)**.

Each additional preventive visit was associated with an 8% reduction in new dental events (95%CI= 5%, 10%) and a 26% reduction in new untreated caries (95%CI= 22%, 29%) **(Table 4.2)**. For children with caries experience at baseline, each visit was associated with a 10% reduction in new dental events (95%CI= 7%, 13%) and 32% reduction in incidence of untreated caries (95%CI= 27%, 36%, and in this group there was also an average 6% per visit reduction in incidence of new restored teeth (95%CI= 2%, 9%). Although primary teeth had a reduction in new dental diseases, permanent teeth had an increase in new restorations, particularly among caries-free children at baseline.

At any time during the first 3 years of ForsythKids, children with caries experience had 2.45 times the hazard of developing the first dental event (95%CI= 2.24, 2.67) compared to children with no previous caries experience (**Table 5.2**). Over half the children who had caries at baseline developed the first dental caries within the first 1 years of the program **(Figure 6.2)**. While more than half of the children who started the program caries-free survived more than 2 years without developing a dental disease. Similar observation was noted in primary and permanent teeth.

Discussion

The overall incidence rate of new dental events reduced with each additional preventive school visit during the mixed dentition stage (between the age of 5-12-year-old children). The exception to this general trend was in permanent teeth, where the incidence of new events was increasing with each additional visit, which is explained by the increase in new restorations, particularly among caries-free children at baseline. Children who enrolled in ForsythKids already having caries experience at baseline, and who are thereby considered at higher risk of new disease, appeared to have benefitted the most as indicated by their lower incidence of new dental events and untreated caries, and stable incidence of new restorations on previously sound teeth, over the 5 follow-up preventive visits. On the other hand, children who were caries-free at baseline had lower hazard of developing initial dental caries than children with caries experience at baseline; their median time to first caries was 1.5 years longer, on average.

Traditionally, dental event has been measured and reported as prevalence of untreated caries, average increase in the decayed, missing and filled index score, or change in the odds of dental caries, even in longitudinal studies. These valid measures are useful to assess widespread of dental diseases in communities, treatment needs or access to care cross-sectionally. The incidence rate measures the intensity of new caries development per unit of time in a population. It is a logical measure to be used in longitudinal cohort studies, yet it has scarcely been reported in the dental literature (Kassebaum, Smith et al. 2017). In their attempt to calculate the incidence of untreated caries in a systematic review, the authors found only 4 studies for which incidence rate of untreated caries in permanent dentition was reported, and none for primary dentition. Because of this gap, they extrapolated rates of untreated caries from prevalence studies.

The rate of caries development in ForsythKids participants was higher than the national average in the time period studied. The incidence of untreated caries in primary dentition in the US was estimated to be 0.242 per 1000 person-days among the US 5-14-year-old children in 2005, and 0.271 per 1000 person-days in permanent dentition of the same age group during the same time (Kassebaum, Smith et al. 2017). At the beginning of the program, ForsythKids population had nearly 5 times the rate of caries in primary dentition, and 1.4 times the rate in permanent dentition compared to the US around the same period in 2005. Even children entering the program with no caries experience, who are generally considered at lower risk of dental decay than children with previous caries, had a higher rate of developing untreated caries than the US average. However, by the 5th preventive visit, caries-free children at baseline had lower rate of untreated caries than the national rate in primary and permanent dentitions, and the rate in permanent dentition among high-risk children was nearly similar to the national average.

To our knowledge, this is the first report to evaluate the rate of developing new dental events. Measuring only untreated dental caries and ignoring newly treated caries tends to understate the true rate of disease development, unless individuals are restricted to seek treatment in the same setting where they are examined. In our findings, we would be underestimating the rate of newly developed events by more than half if only untreated caries was measured. Whereas untreated caries often reflects an unmet need for treatment, the increasing rate of new restorations with additional school visits, accompanied by a reduction in untreated caries, reflects an increase in access to appropriate treatment when needed. Although a higher access to dental services is desired, higher new restorations can also be a sign of failed preventive care.

School-based delivery has been recommended by U.S. federal and national agencies as a means to increase access to preventive care, improve academic performance, and reduce health disparities (Center for Health and Health Care in Schools 2012, Knopf, Finnie et al. 2016). ForsythKids provides exceptionally comprehensive preventive care, which was found to be cost-effective compared to the standard clinical care (Bukhari 2016). Comparable to the traditional school-based programs, high-risk children benefited the most from the comprehensive prevention provided. In addition, ForsythKids helps fulfill one of the Healthy People 2020 goals of increasing the proportion of oral health services in school-based health centers (US Department of Health Human Services and Office of Disease Prevention and Health Promotion 2010).

The prospective cohort design of ForsythKids enabled estimation of incidence rates. But the program was designed to deliver care to all participating children, so we lacked a comparable non-exposed group. However, estimating the longitudinal trends provided evidence of program effectiveness. Furthermore, the participation rate in ForsythKids was low, ranging between 10%-29%, which increases the probability of selection bias of our sample. Although we were using 6 years of follow-up between 2004-2010, the most recent data in our analysis was from a decade ago. Nevertheless, the dental landscape has not changed notably since, and the effectiveness demonstrated are still valid and relevant. Moreover, teeth missing due to caries was not be calculated in our analysis. We were limited to this approach since there is no information from the clinical notes on the reasons of missingness, whether due to caries or otherwise. We understand this might underestimate the true disease burden in primary teeth, however, missing permanent teeth in this age group is unlikely. Lastly, there are potential mistakes in recording of tooth-colored restorations or sealants in the clinical records. Meaning, tooth-colored restorations could be missed in prior visits (false negative), or sealants could be mistakenly counted as a restoration in a subsequent visit (false positive).

Conclusions

ForsythKids shown effective to lower the burden of caries. The overall incidence of new dental events decreased with each additional preventive visit, while new restorations on previously sound teeth increased in permanent dentition. Comprehansive school-based preventive care was beneficial the most for high-risk children with caries expirence. However, they were at a higher risk to develop the caries first compared to their caries-free peers.

Table 1.2: Baseline characteristics among children receiving school-based dental oral health care through the ForsythKids program with ≥1 visit post-baseline, 2004-2010

Characteristics	Frequency(n)/ Mean(unit)	Percent/SD[a]
Sex (n=5,265)		
Female	2,645	50%
Male	2,620	50%
Age (n=5,307)		
5	828	16%
6	1,266	24%
7	1,093	21%
8	893	17%
9	629	12%
10	380	7%
11	178	3%
12	40	1%
Reported race (n=1,745)		
White	1,209	54%
African American	393	19%
Asian	230	11%
Multiracial	278	13%
Other	50	2%
Experienced caries at baseline (n=5,307)		
Permanent	831	16%
Primary	2,652	50%
Both	2,859	54%
Number of children/school (average)	319 children	198 children
Average number of visits	Mean: 3.14 visits Median: 3 visits	SD: 1.45 visits Interquartile range: 2 visits
Number of children at each visit		
Baseline visit	6,927	38%
1	5,307	29%
2	2,690	15%
3	1,824	10%
4	862	5%

5	457	3%
Years in the program (n=5,307)	Mean:1.24 years Median: 1 year	SD: 0.96 year Interquartile range: 1.28 years
Baseline oral health		
Primary dentition		
dft[b]	1.9 teeth	2.5 teeth
Permanent dentition		
DFT[c]	0.4 teeth	0.9 teeth

[a] Standard deviation

[b] dft: Decayed and filled primary teeth

[c] DFT: Decayed and filled permanent teeth

Table 2.2: Incidence rate (IR) per 1000 person-days at each post-baseline preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

Number of the visit (post baseline)	Both dentitions			Primary dentition			Permanent dentition		
incidence rate of new dental events (untreated or restored teeth)/1000 person-days									
	IR	95%CI		IR	95%CI		IR	95%CI	
1	4.13	3.96	4.30	2.79	2.66	2.92	1.55	1.46	1.64
2	3.37	3.17	3.57	1.60	1.47	1.72	1.91	1.78	2.05
3	3.32	3.08	3.56	1.32	1.18	1.46	2.19	1.00	2.37
4	3.28	2.93	3.62	1.19	0.99	1.38	2.33	2.06	2.60
5	3.26	2.77	3.74	0.96	0.71	1.21	2.58	2.17	3.00
incidence rate of new untreated caries/1000 person-days									
1	1.47	1.38	1.55	1.17	1.09	1.24	0.38	0.34	0.41
2	0.98	0.89	1.06	0.68	0.60	0.75	0.35	0.30	0.40
3	0.88	0.77	0.98	0.65	0.56	0.74	0.30	0.24	0.36
4	0.59	0.47	0.71	0.50	0.38	0.61	0.16	0.10	0.22
5	0.40	0.26	0.55	0.35	0.21	0.49	0.12	0.04	0.19
incidence rate of new restorations/1000 person-days									
1	2.58	2.46	2.70	1.55	1.46	1.64	1.16	1.09	1.24
2	2.36	2.21	2.52	0.89	0.80	0.98	1.56	1.44	1.68
3	2.40	2.20	2.59	0.63	0.54	0.72	1.88	1.71	2.05
4	2.71	2.41	3.01	0.66	0.52	0.80	2.19	1.92	2.45
5	2.89	2.44	3.34	0.59	0.40	0.79	2.48	2.07	2.88

Table 3.2: Incidence rate (IR) per 1000 person-days stratified by baseline oral health status at each post-baseline preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

Number of the visit (post-baseline)	Both dentitions						Primary dentition						Permanent dentition					
Baseline dental health status	Caries-free			Had caries experience			Caries-free			Had caries experience			Caries-free			Had caries experience		
Incidence rate of new dental events (untreated or restored teeth)/1000 person-days																		
	IR	95%CI		IR	95%CI		IR	95%CI		IR	95%CI		IR	95%CI		IR	95%CI	
1	1.58	1.45	1.71	6.37	6.05	6.69	1.32	1.21	1.44	4.20	3.96	4.45	1.06	0.99	1.14	3.98	3.57	4.39
2	1.55	1.38	1.73	4.89	4.54	5.24	1.07	0.93	1.21	2.09	1.88	2.29	1.50	1.38	1.63	3.65	3.17	4.12
3	1.62	1.40	1.85	4.81	4.34	5.24	1.05	0.87	1.23	1.60	1.37	1.82	1.71	1.53	1.88	4.27	3.59	4.96
4	1.48	1.17	1.79	4.80	4.18	5.41	0.90	0.66	1.14	1.47	1.16	1.77	1.92	1.65	2.19	4.28	3.26	5.29
5	1.41	0.97	1.86	4.73	3.89	5.57	0.99	0.61	1.36	0.97	0.63	1.31	2.33	1.90	2.77	3.63	3.37	4.90
Incidence rate of new untreated caries/1000 person-days																		
1	0.85	0.78	0.93	2.84	2.61	3.07	0.70	0.64	0.77	2.33	2.11	2.54	0.28	0.25	0.32	1.35	1.08	1.62
2	0.62	0.54	0.71	1.67	1.46	1.88	0.45	0.38	0.52	1.20	1.01	1.38	0.30	0.25	0.36	0.82	0.58	1.06
3	0.69	0.58	0.81	1.27	1.05	1.50	0.55	0.45	0.65	0.91	0.70	1.11	0.29	0.23	0.35	0.44	0.23	0.65
4	0.38	0.26	0.50	1.01	0.74	1.28	0.32	0.21	0.44	0.89	0.61	1.17	0.12	0.07	0.18	0.56	0.19	0.93
5	0.26	0.12	0.41	0.69	0.38	1.01	0.25	0.10	0.39	0.58	0.26	0.91	0.10	0.31	0.18	0.25	0.00	0.61
Incidence rate of new restorations/1000 person-days																		
1	1.41	1.30	1.51	4.60	4.30	4.90	0.98	0.90	1.06	2.61	2.40	2.82	0.93	0.86	0.99	3.35	2.88	3.81
2	1.48	1.34	1.63	3.79	3.44	4.13	0.72	0.62	0.81	1.19	1.02	1.36	1.37	1.26	1.49	3.02	2.48	3.55
3	1.61	1.41	1.80	3.68	3.26	4.11	0.62	0.51	0.74	0.64	0.49	0.80	1.58	1.42	1.74	4.22	3.34	5.10
4	1.88	1.58	2.18	4.08	3.52	4.74	0.64	0.48	0.81	0.69	0.46	0.93	1.98	1.72	2.23	4.28	2.80	5.75
5	2.11	1.63	2.59	4.08	3.19	4.97	0.83	0.54	1.12	0.21	0.04	0.39	2.34	1.93	2.75	3.56	1.80	5.32

Table 4.2: Change in Incidence associated with each additional preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

Estimate	Both dentitions			Primary dentition			Permanent dentition		
	IRR[a]	95%CI[b]		IRR	95%CI		IRR	95%CI	
		Lower value	Upper value		Lower value	Upper value		Lower value	Upper value
New dental events (untreated or restored teeth)									
All patients	0.92	0.90	0.95	0.72	0.69	0.75	1.15	1.12	1.19
Caries-free at baseline	0.99	0.94	1.04	0.89	0.84	0.95	1.22	1.18	1.27
Caries experience at baseline	0.90	0.87	0.93	0.65	0.62	0.68	1.01	0.95	1.07
New untreated caries									
All patients	0.74	0.71	0.78	0.73	0.69	0.77	0.82	0.76	0.88
Caries-free at baseline	0.81	0.76	0.86	0.80	0.74	0.86	0.86	0.79	0.94
Caries experience at baseline	0.68	0.64	0.73	0.67	0.62	0.72	0.65	0.55	0.77
New restorations									
All patients	1.01	0.98	1.04	0.70	0.67	0.74	1.23	1.19	1.27
Caries-free at baseline	1.10	1.05	1.14	0.87	0.82	0.93	1.27	1.23	1.32
Caries experience at baseline	0.94	0.91	0.98	0.54	0.50	0.59	1.07	0.99	1.17

[a] IRR: incidence rate ratio

[b] 95% confidence interval

Table 5.2: Hazard ratio (HR) of the of first new dental event (untreated or restored tooth) among children with caries experience at baseline compared to caries-free children within 3 years from receiving school-based dental oral health care through the ForsythKids program, 2004-2010

Variables	HR[a]	95% CI[b]	
		Lower value	Upper value
Caries-free children at baseline	Ref.	Ref.	Ref.
Both dentitions			
Caries experience at baseline	2.45	2.24	2.67
Primary dentition			
Caries experience at baseline	2.27	2.06	2.51
Permanent dentition			
Caries experience at baseline	1.86	1.68	2.07

[a] HR: hazard ratio

[b] 95% confidence interval

Figure 3.2: Incidence rate (IR) of new dental events (untreated or restored teeth) per 1000 person-days at each post-baseline preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

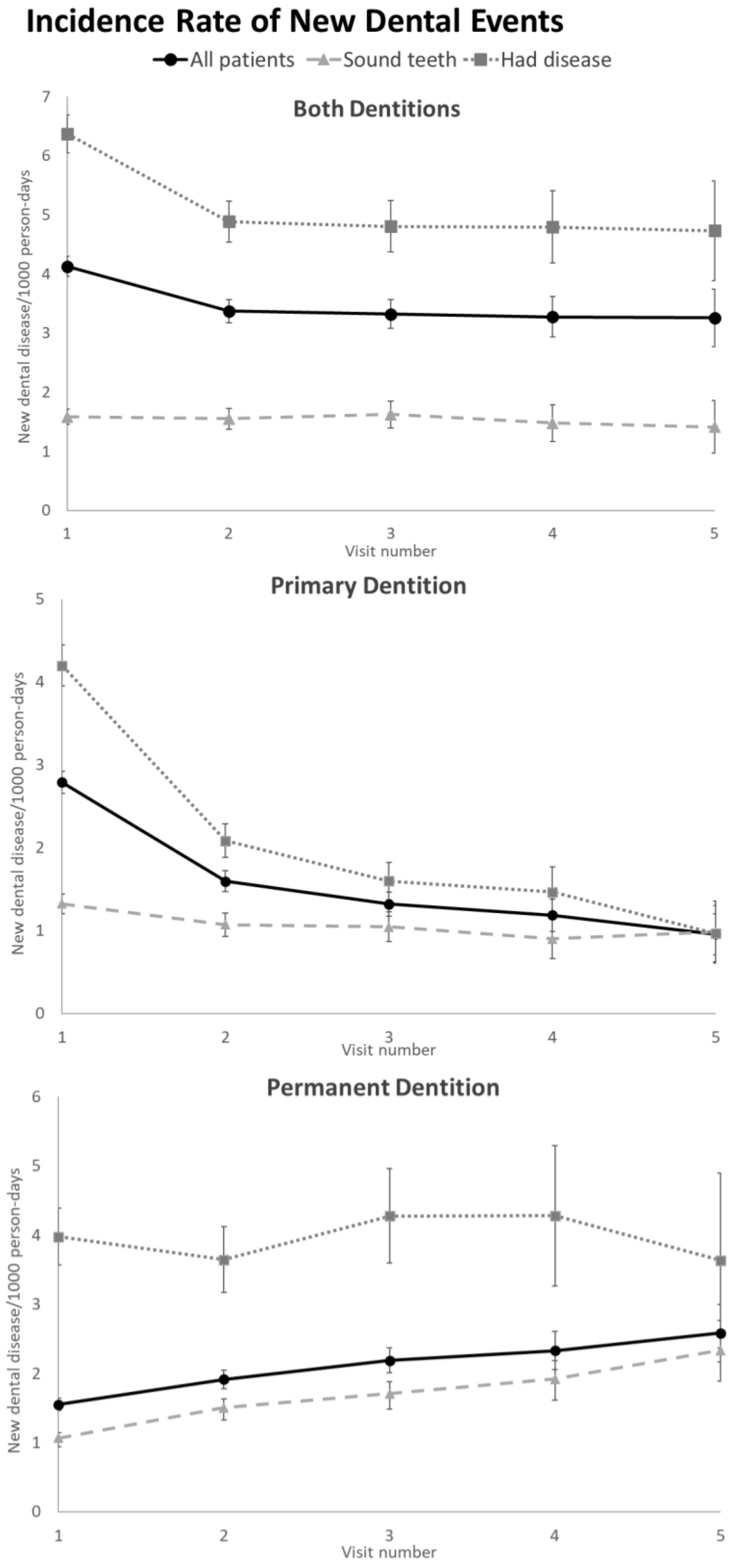


Figure 4.2: Incidence rate (IR) of new untreated caries per 1000 person-days at each post-baseline preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

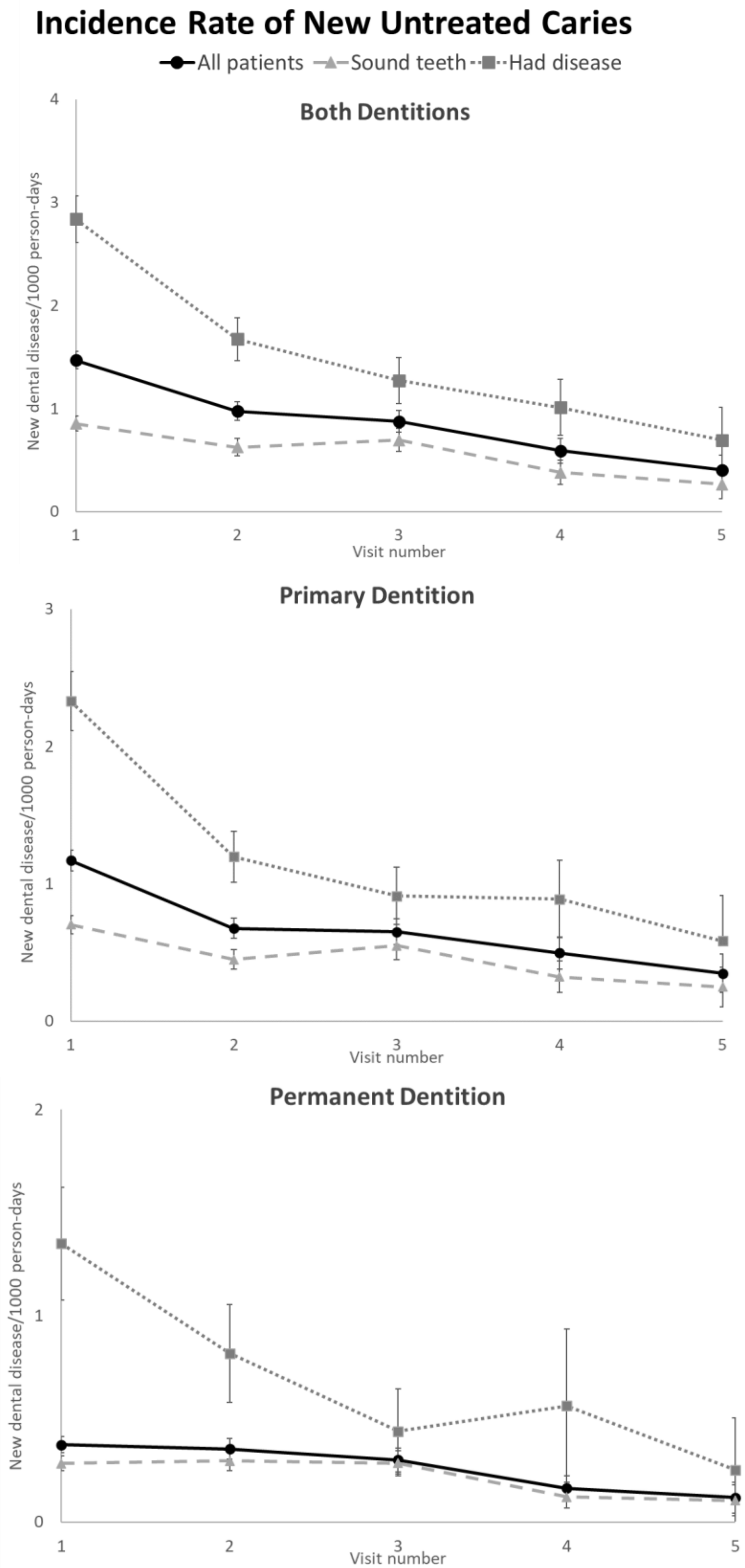


Figure 5.2: Incidence rate (IR) of new restorations per 1000 person-days at each post-baseline preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

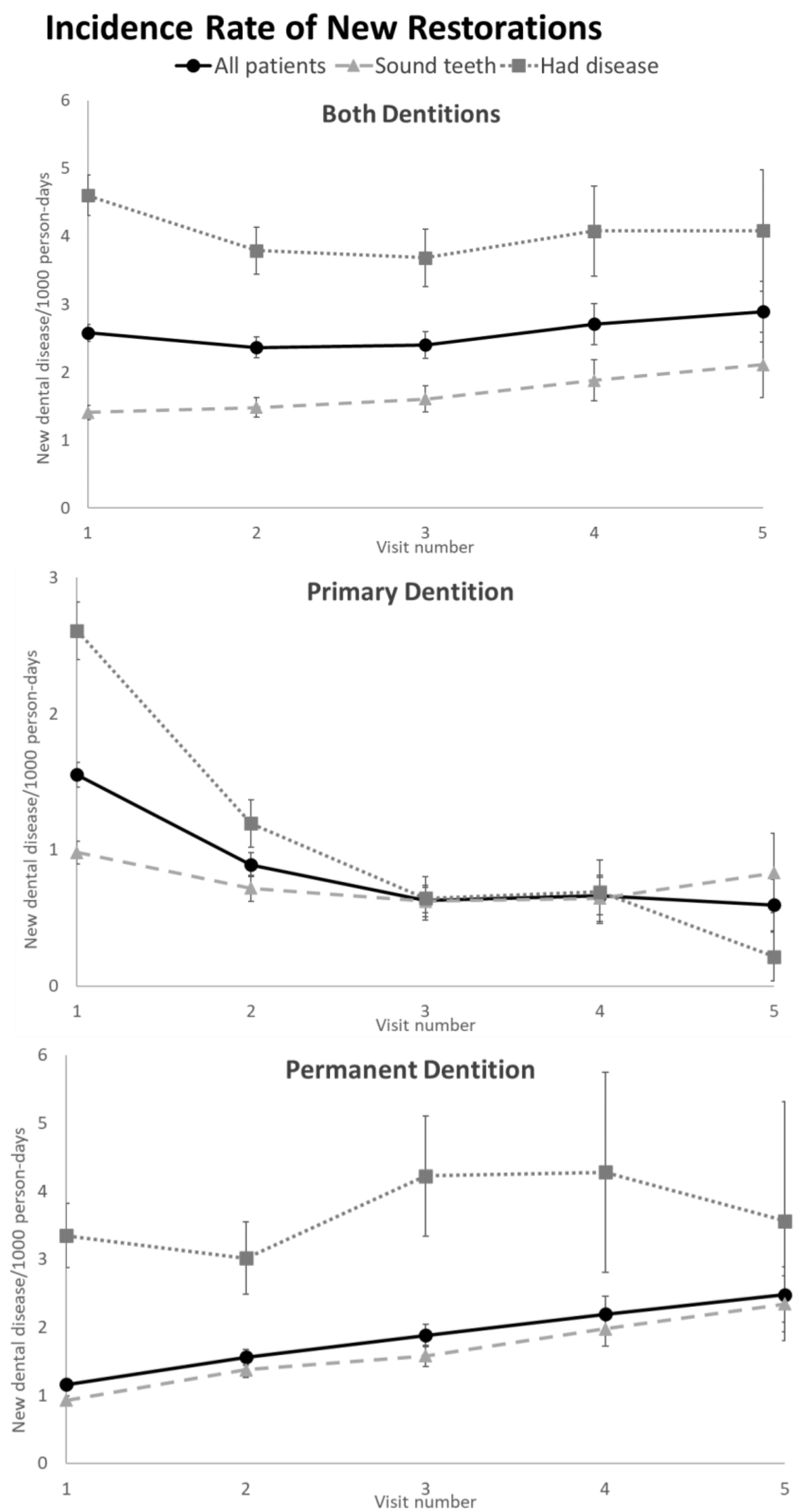
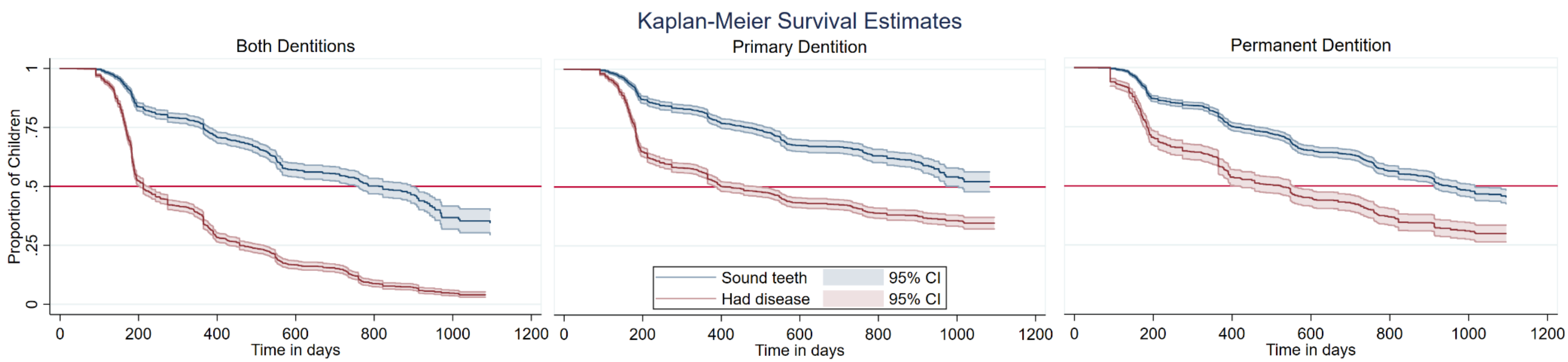


Figure 6.2: Time to the first new dental event (untreated or restored tooth) comparing children with caries experience at baseline compared and caries-free children within 3 years from receiving school-based dental oral health care through the ForsythKids program, 2004-2010



Chapter Three:

New Dental Health Metric

Proportions of Sound Teeth (PST)

Abstract

Objectives: To develop a new index to measure dental health preservation as an outcome, Proportion of Sound Teeth index (PST), describe how to calculate the different variations of PST, apply cross-sectional (xPST) and cumulative (cPST) to evaluate ForsythKids data, and compare results to those obtained with the conventional index, decayed and filled teeth (DFT).

Methods: The three variations of PST are: xPST provides a cross-sectional measure of dental health at a point in time, iPST is the instantaneous proportion of sound teeth that is still sound compared to a previous time point; and cPST is is an extension of iPST that compares the preservation of dental health over multiple time points since a common baseline. PST values ranges between 100% for perfect health, to 0%. Based on the child's age, two different denominators can be used calculate the PST: observed sound teeth (c_o), or teeth at current or future risk (c_e). We analyzed data from ForsythKids, a comprehensive school-based caries prevention program serving Title 1 elementary schools in greater Boston. All patients seen from 2004-2010 were eligible for inclusion in data analysis. We estimated xPST at baseline and the the average change in cPST and DFT over 5 post-baseline visits.

Results: The total number of children was 5,307 in 33 schools. xPst for primary dentition was 83.6%, with an average dft of 1.8 teeth, while DFT in permanent dentition was 0.4 teeth and xPST was 96.7% using the same constant c_o. The average increase in dft score was 15% per visit (95%CI=15%, 16%) in the primary dentition, while the reduction in cPst was 3.7 percentage points (points) per visit (95%CI: 3.8 points, 3.6 points) using c_o. In permanent dentition, there

was a 1.6-point reduction in cPST per visit using c_e (95%CI: 1.6 points, 1.5 points), but a 50% increase in DFT score (95%CI=50%, 50%). Children with caries experience at baseline had a steeper reduction in cPST, while caries-free children had a steeper increase in DFT scores.

Conclusion: The goal of preventive programs is to maintain healthy teeth as long as possible. In contrast to the current metrics for evaluating preventive dental programs, which focus on disease risk, prevalence, or intensity, the PST focuses on the maintenance of health, i.e. sound teeth. The PST could be a valuable tool for evaluating the effectiveness of caries prevention programs or modalities.

Introduction

Dental caries is the most prevalent disease in the world, with more than 3 billion people globally suffering from active, untreated tooth decay (Kassebaum, Bernabe et al. 2015, Kassebaum, Smith et al. 2017). In 2016, the United States (US) spent $124 billion on dental care, which accounted for 3.6% of all health care expenditure that year (Garvin 2017). There are many safe and effective preventive interventions, ranging from water fluoridation at the community level to professionally applied sealants and fluoride varnish at the individual level, to name a few (U.S. Department of Health and Human Services 2000, Quah and Cockerham 2017). Many have long believed that dental care is overly dependent on a reactive clinical approach and should better emphasize a more proactive, cost-effective preventive approaches (U.S. Department of Health and Human Services 2000, Community Preventive Services Task Force 2013, Community Preventive Services Task Force 2013, Marinho, Worthington et al. 2013). However, the tools we use to assess effectiveness of programs or specific interventions quantify the extent of disease rather than the maintenance of health and thus are misaligned with program goals.

The most common metric for representing the dental health of individuals or communities or for tracking the effectiveness of caries preventive programs has been by applying a composite index that is a simple count of all decayed, missing and filled surfaces or teeth (DMFS or DMFT, respectively, for permanent teeth, and dmfs or dmft for primary teeth) (Klein, Palmer et al. 1938). The DMF index was developed in 1938, with subsequent variations introduced provide more flexibility, including: DF & df components only if it's hard to determine the reason of missingness; DMFS & dmfs to account for pits & fissure sealants;

significant caries index (SiC) to represent the skewed distribution of caries, which is the average DMF score among the highest third affected by caries (Bratthall 2000).

The DMF has been extremely useful for research and public health surveillance, but it also has several limitations (Burt and Eklund 2005). First, DMF measures caries in absolute numbers, hence, it does not convey any information about the teeth at risk or intensity of disease attack. Second, the DMF index conflates disease and its treatment, since untreated and treated caries are counted the same. Third, and more fundamental to our goals, all the three components of DMF measure and describe the state of disease experience, not the state or maintenance of dental health. Other indices have been designed to address some of these limitations, including Grainger's hierarchy and the T-Health indices (Poulsen and Horowitz 1974, Bernabe, Suominen-Taipale et al. 2009). Yet, all are measures of disease, when it may often be more desirable to estimate maintenance of health in evaluating the effectiveness of preventive care.

Here, we propose a new metric, the Proportion of Sound Teeth index (PST), which measures dental health preservation. The PST can be used cross-sectionally (xPST), to measure dental health of an individual or community at a point in time, or longitudinally. The iPST measures the instantaneous proportion of sound teeth that has remained sound since a previous time point, and the cPST measures the cumulative proportion of sound teeth remaining sound over multiple time points with reference to a common baseline time point. The objective of this paper is to describe how to calculate the different variations of PST. In addition, we applied xPST and cPST in a school-based preventive program, comparing results with those obtained by using the standard DFT index.

Material and Methods

Each variation of PST has different indication, method of calculation, and interpretation **(Table 1.3)**. The index is calculated separately for the primary or permanent dentition, with the index for primary teeth denoted Pst. At any given time, the average xPST provides a snapshot of a population's dental health. It communicates information about the remaining dental health, by dividing the number of sound teeth by the total number of teeth. The value ranges between 100% for perfect health, to 0%. As a longitudinal metric, iPST is useful to compare the dental health status between any two specific time points, between time k (t_k) to a previous time point k-1 (t_{k-1}). Likewise, cPST is an extension of iPST that compares the preservation of dental health over multiple time points since some baseline (t_0).

To calculate xPST, divide the number of sound teeth (*c*) at any t_k by the total number of sound teeth and DMFT at the same time point **(Table 1.3)**. The denominator for iPST or cPST at any t_k is the number of sound teeth at risk (*c*) at t_{k-1} for iPST, and at baseline t_0 for cPST, excluding 3rd molars. By definition, sound teeth also exclude any decayed, missing or filled teeth. In the nominator, subtract *c* from the difference in DMFT between t_k and the reference point. At a baseline point in time, the index value begins at 100%. During follow-up, the value of iPST or cPST can only decline or remain unchanged and is bounded between 0-100%. These two properties require having a constant *c* in the denominator to prevent the index from increasing over time or from having values above 100%. Yet, considering the dynamic nature of tooth eruption and exfoliation, it is not obvious how *c* should be fixed. We propose two methods to calculate the constant *c*, each with different indications, assumptions, and implications. For either method, *c* has a maximum value of 28 sound teeth for PST, and 20 sound teeth for Pst.

1. **Constant using observed teeth at baseline** (c_o):

At baseline, the observed constant c_o is the number of erupted teeth present and sound at examination. Using the baseline number c_o throughout the follow-up period potentially underestimates *c* as new teeth erupt. Thus, using c_o in the denominator is best used only when children have their full set of teeth erupted, typically ≥3 years for primary teeth and ≥13 years for permanent teeth. The assumption that no new teeth will erupt over time can lead to conservative estimates of PST and Pst, which is potentially more reflective to the true estimation of the community health status or the preventive effect of a program.

2. **Constant using sound teeth at current or future risk, including the unerupted teeth** (c_e):

The expected constant c_e assumes all sound teeth are at risk, including those not yet erupted, and excluding exfoliated primary or extracted teeth. This method may be preferred in longitudinal tracking that is initiated when children are still dentating, so that the denominator remains constant over time. This would typically be between 0-3 years for primary teeth, and 5-13 years for permanent teeth. PST measures based on c_e may be prone to exaggerating either the degree of health (xPST) or preventive efficacy (iPST and cPST) at some follow-up visits, because the denominator would include teeth that are not yet at risk.

Describing the program setting: ForsythKids

ForsythKids is a comprehensive school-based preventive program that aims to improve access to primary dental care among underserved children. Schools in the greater Boston area are eligible to join ForsythKids program if they are under Massachusetts Title I of the federal Elementary and Secondary Education Act, with more than 50% children receiving federal free and reduced-cost meals programs. ForsythKids started in the spring of 2004 with a total of 6 elementary schools. By 2017, ForsythKids was serving close to 60 schools. The program provides children with a range of services, from oral hygiene instruction, sealants and fluoride varnish, to referrals for active dental disease. Portable clinics are used to deliver care at each school site. All children participating in ForsythKids are eligible to receive three annual preventive visits, defined as receiving either prophy cleaning, fluoride varnish or pits & fissure sealants, or any combination of these.

During the years included in this study, at the beginning of each academic year, children were given consent forms, along with all other school forms, to be signed by their guardian. Schools or individual children could drop out of the program at any time.

Statistical Analysis

We used data from the clinical records of the program from its inception in month, 2004 to December 2010. All patients were eligible who were between age 5-12 years of age, with at least one preventive visit post-baseline. We limited the analysis to within 5 follow-up visits beyond baseline (or 6 visits total), due to the small numbers of children with visit numbers above this threshold.

The outcomes of interest were: xPst, cPst and dft for primary dentation; and xPST, cPST and DFT for permanent dentation. We used only the observed *c* in calculating xPst and cPst. For permanent teeth, we used c_e to calculate cPST, and we used both constants, c_o and c_e, to estimate xPST in two different ways. We used DFT rather than DMFT in all calculations, because the clinical notes provided no reason for missing teeth, whether due to caries, natural exfoliation, or otherwise. We evaluated the temporal trends of cPst & cPST over the number of preventive care visits.

We first summarized results descriptively, estimating frequencies with percentages, and averages with standard deviations (SD) for ForsythKids characteristics, as well as for the xPST and xPst at baseline. To estimate the average change in DFT and cPST with each preventive visit, we used Generalized Estimating Equations (GEE), with exchangeable correlation to account for individual clustering of the outcomes over number of visits. Within the GEE framework, we fitted linear regression models for the cPST outcome and negative binomial models for the DFT outcome, which has a count distribution. We reported the estimates and its respective 95% confidence intervals (95%CI). In addition, we reported the estimates stratified by the presence of dental caries at baseline. All the data analyses were performed using StataSE 15.1 (StataCorp, College Station, Texas).

Results

Out of total 6,927 children, the final sample had 5,307 children who had at least one post-baseline visit, with 50% males and the majority in grades one, two, or three at their baseline visit **(Table 2.3)**. On average, 319 students/school were enrolled in the program. Students had an average 3.14 visits (SD ± 1.45 visits), spanning over 1.24 years (SD ± 0.96). Half the children had experienced caries in their primary teeth when they were first examined, while 16% had caries experience in their permanent teeth. In total, 54% of all students had any caries experience at their first visit.

At baseline, the average dft and DFT scores were, respectively, 1.9 teeth (SD±2.5) and 0.4 teeth (SD±0.9). The average xPST was 96.9% (SD ± 8.1%) using c_o and 98.7% (SD±3.4%) using c_e. The average xPst for primary dentation was 83.8% (SD±21.9%).

Over time, the average dft increased an estimated 1.15-fold with each additional visit (95%CI= 1.15, 1.16) in primary dentation **(Table 3.3)**. The corresponding estimated average per-visit decrease in the cPst was 3.68 percentage points (PP) reduction (95%CI= -3.78, -3.58). Stratifying by baseline caries experience, those who were caries-free had a greater per-visit increase in their dft score **(Figure 1.3)** and shallower reduction in cPst **(Figure 2.3)** compared with children who had caries at baseline. These results were similar for the permanent dentation.

Discussion

We described several forms of a novel, health-focused oral index, PST, which can be used to monitor a previously obscured, yet important, aspect of oral health, i.e. the proportion of teeth that are healthy and intact. This new index can be used as an adjunct; in addition to using standard metrics to quantify extent of disease through number of decayed or filled teeth, investigators can use the PST to quantify and communicate dental health. Moreover, variants of the PST allow it to be applied at a given age or timepoint through xPST, while also offering version for longitudinal application (iPST and cPST). For example, the latter could be used to report the effectiveness of policy initiatives or clinical care in maintaining sound teeth disease-free over time.

In the ForsythKids prevention program between 2004-2010, more than half of the children had experienced caries by the time they joined the program. On average, 84% of primary teeth and over 96% of the permanent teeth were sound at baseline. Both dft and DFT increased, on average, with each additional preventive visit, and these indices of disease increased more quickly among children who were caries-free at baseline than in children who entered the program with caries experience. Accordingly, the rate of reduction in cPST and cPst was higher among the higher risk group, those with disease at baseline. The extent of health reduction depended on the number of sound teeth at baseline: the fewer sound teeth at baseline, the faster the PST index will gravitate toward zero with each additional tooth that succumbs to decay. Hence, the larger the value of preserving health among the most vulnerable, highest-risk population.

As an adjunct to the DFT indices, which are absolute numbers, the xPST conveys extra information about the intensity of caries experience using c_o, as well as the amount of potential dental health that could be preserved. When used longitudinally in evaluating effectiveness of policies, clinical care, or interventions, the iPST & cPST isolate the preventive impact. Cl Bukhari's doctoral dissertation (Bukhari 2016). He described the method of the iPST index, under the name of Proportion of Sound Teeth (PrST), and he applied it to measure ForsythKids instantaneous effectiveness in maintaining sound teeth over visits. Bukhari found the instantaneous effectiveness increased as children stayed in the program for longer, from 98.6% of primary and permanent sound teeth remained sound at the second visit, to 99.2% maintenance of sound teeth by the seventh visit compared to the previous visit. Furthermore, he did not find a difference stratifying by dentation type. The fact that permanent teeth are erupting in some age groups, putting the denominator into flux, we suggest fixing the denominator of iPST as the number of sound teeth from the earlier visit. In contrast, the cumulative proportion cPST measures the sound teeth remaining sound over multiple timepoints since a reference baseline. Instead of re-scaling the proportion of sound teeth to 100% at each timepoint k, we built the memory into cPST that can track the amount of reduction and remaining health to a reference point in time.

The method of measurement influences our mindset towards oral health, and it affects our attitude of treating disease or maintenance of health. It is maybe practical for policymakers to use a disease index in surveillance systems to assess the treatment needs and allocate resources. However, it is more logical to measure the preservation of community health to evaluate the impact of preventive initiatives, as well as measuring the effectiveness of clinical care among clinicians. At the patient level, PST could be a useful communication tool that helps frame dental status in the positive health domain, instead of in terms of disease. Prospect theory in behavioral economics suggests that individuals are loss averse, and framing dental disease as loss of health can motivate patients and policymakers to embrace more preventive practices (Kahneman and Tversky 1979). Empirical evidence demonstrates this is especially helpful among those with no prior intention to change (Detweiler, Bedell et al. 1999, Rothman, Martino et al. 1999, Moxey, O'Connell et al. 2003).

Because PST is built on the DMFT index, it has some if of its inherent limitations, including the equal weight given to well-restored, untreated, or missing teeth, any of which can be the reason a tooth becomes unsound. For example, teeth can be missing due to disease or for other reasons, such as injury or orthodontic treatment, each of which has different implications for health and further disease susceptibility. Because we did not include missing teeth in the analysis, dft tends under-estimate the disease experience and Pst could over-estimate the preventive effectiveness of ForsythKids in primary dentation. Ignoring missing teeth has a lesser influence on PST estimation, since missing teeth at the age group is uncommon. Moreover, xPST in population surveys, like DMFT, provides little information to determine treatment needs (Burt 1997). Nevertheless, the familiarity with DMF makes adopting and understanding PST easier. Since it does not require a different method or tool for clinical evaluation, PST can even be applied to historical and published data where DMFT only was calculated, as long as the number of sound teeth is measured at baseline or at any time xPST is to be calculated.

The main challenge of using iPST & cPST is when teeth are erupting, typically between 0-3 years for primary teeth, and 5-13 years for permanent teeth. The method we suggested to address this limitation is to use the c_e instead of the c_o during these age ranges, so that the denominator is constant over time. While the c_e has the potential to over-estimate the impact of the preventive programs in these age groups, it prevents the iPST & cPST values from increasing over time and from exceeding 100%.

Among the limitations of the clinical data used for analysis is the inability to evaluate the changes in PST in a comparable, non-exposed, control group. Moreover, only children 5-year or older were eligible to participate in ForsythKids, and during the time period we studied, they were administratively censored over the age of 12. This inclusion/exclusion criteria limited us from evaluating the performance of PST using different constants among children growing out of the tooth-erupting stage.

The PST can also be expanded to other variations, such as measuring the proportion of sound surfaces (PSS) or proportion of sound roots (PSR). In addition, PST can be reported for specific subsets of teeth, such as the posterior teeth (PST-p), which are at higher risk of disease, or anterior teeth (PST-a), because a reduction in anterior health indicates a high-risk individual or population. The concept of proportion of health could be used in periodontal health as well (PSP).

Conclusions

Within the limitations of the study, the average increase in dft and DFT scores were higher with each additional visit among caries-free children at baseline, while children with caries experience had steeper reduction in their dental health through cPst and cPST. PST offers another index that could be added to our toolbox of measurements to evaluate oral health among individuals and communities, instead of only measuring disease. It is the logical tool to use in evaluating the effectiveness of preventive care or initiatives.

Table 1.3: Variations of PST index, purpose and mathematical methods

PST index	Purpose	Unit	Mathematical Formula
xPST	cross-sectional proportion of remaining sound teeth at any time point	Sound teeth remaining	$\mathrm{xPST}(t_k) = \frac{c(t_k)}{c(t_k) + \mathrm{DMFT}(t_k)}$
iPST	instantaneous proportion of sound teeth that are still sound compared to a previous time point	Sound teeth remined sound between t_{k-1} and t_k	$\mathrm{iPST}(t_k) = \frac{c(t_{k-1}) - [\mathrm{DMFT}(t_k) - \mathrm{DMFT}(t_{k-1})]}{c(t_{k-1})}$
cPST	cumulative proportion of sound teeth that remain sound over multiple time points	Sound teeth remined sound since t_0	$\mathrm{cPST}(t_k) = \frac{c(t_0) - [\mathrm{DMFT}(t_k) - \mathrm{DMFT}(t_0)]}{c(t_0)}$

Abbreviations: PST: Proportion of sound teeth, c: Number of sound teeth, DMFT: Decayed, missing and filled teeth, t_k= At a given time point k, t_0=At baseline

In primary dentation: use Pst instead of PST, and deft instead of DMFT. Exclude 3rd molars in permanent dentation.

Table 2.3: Baseline characteristics among children receiving school-based dental oral health care through the ForsythKids program with ≥1 visit post-baseline, 2004-2010

Characteristics	Frequency(n)/ Mean(unit)	Percent/SD[a]
Sex (n=5,265)		
Female	2,645	50%
Male	2,620	50%
Age (n=5,307)		
5	828	16%
6	1,266	24%
7	1,093	21%
8	893	17%
9	629	12%
10	380	7%
11	178	3%
12	40	1%
Reported race (n=1,745)		
White	1,209	54%
African American	393	19%
Asian	230	11%
Multiracial	278	13%
Other	50	2%
Experienced caries at baseline (n=5,307)		
Permanent	831	16%
Primary	2,652	50%
Both	2,859	54%
Number of children/school (average)	319 children	198 children
Average number of visits	Mean: 3.14 visits Median: 3 visits	SD: 1.45 visits Interquartile range: 2 visits
Number of children at each visit		
Baseline visit	6,927	38%
1	5,307	29%
2	2,690	15%
3	1,824	10%
4	862	5%

5	457	3%
Years in the program (n=5,307)	Mean:1.24 years Median: 1 year	SD: 0.96 year Interquartile range: 1.28 years
Oral health indicators		
Primary dentation		
dft[b]	1.9 teeth	2.5 teeth
xPst[c]		
-Using c_o*	83.8%	21.9%
Permanent dentation		
DFT	0.4 teeth	0.9 teeth
xPST		
-Using c_o	96.9%	8.1%
-Using c_e†	98.7%	3.4%

[a] Standard deviation

[b] dft: Decayed and filled teeth

[c] Proportion of sound teeth at baseline

* Denominator of observed sound teeth only

† Denominator of sound teeth at current or future risk, including the unerupted teeth

Table 3.3: Estimated change in oral health indicators with each additional preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

Oral health indicator	Expected change (all children)	95%CI[a]		Expected change					
		Lower value	Upper value	Caries-free at baseline	95%CI Lower value	95%CI Upper value	Had caries at baseline	95%CI Lower value	95%CI Upper value
Primary dentation									
dft[b] (mean ratio)	1.15	1.15	1.16	1.87	1.82	1.92	1.12	1.10	1.14
cPst									
c_o^* (PP)[c]	-3.68	-3.78	-3.58	-1.61	-1.76	-1.46	-5.59	-5.73	-5.44
Permanent dentation									
DFT (mean ratio)	1.49	1.46	1.51	2.08	2.03	2.12	1.29	1.26	1.33
cPST									
$c_e^\dagger$ (PP)	-1.56	-1.60	-1.53	-1.17	-1.21	-1.13	-3.34	-3.42	-3.25

[a] 95% confidence interval

[b] dft: Decayed and filled teeth

[d] Percentage points

* Denominator using observed sound teeth only

† Denominator using sound teeth at current or future risk, including the unerupted teeth

Figure 1.3: Average decayed and filled teeth at each preventive visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010

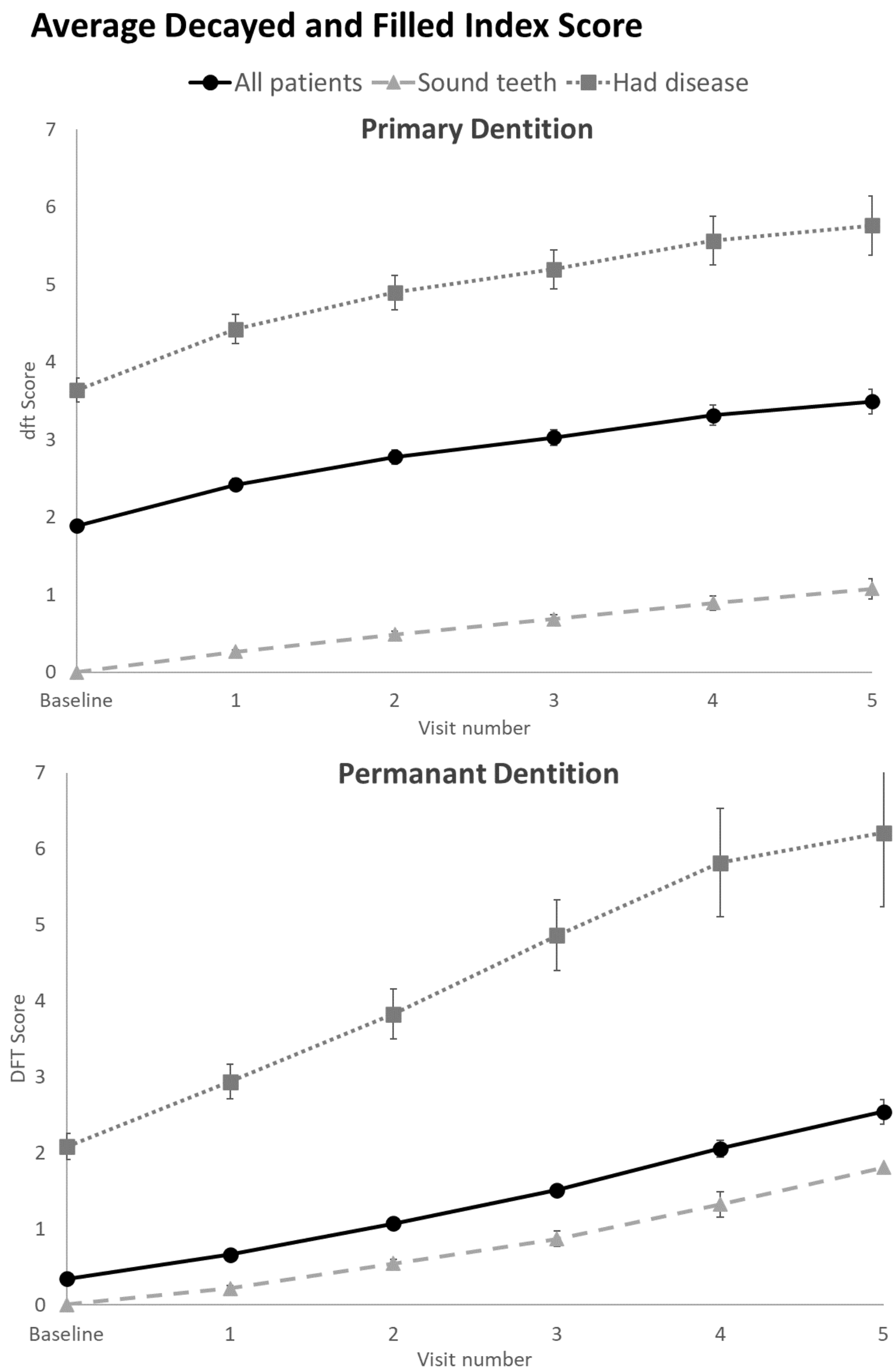
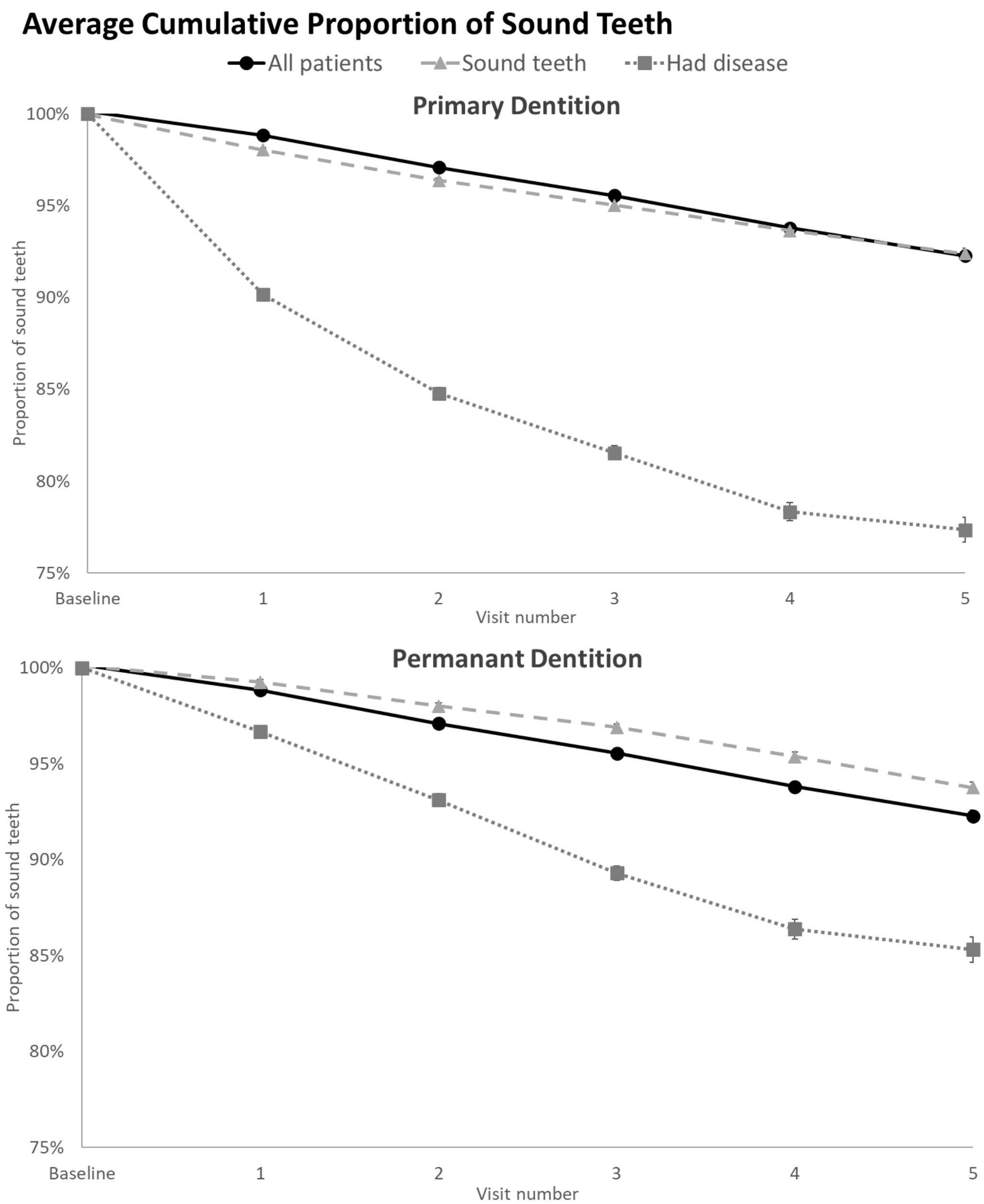


Figure 2.3: Average cumulative proportion of sound teeth (cPST) since baseline visit among children receiving school-based dental oral health care through the ForsythKids program, 2004-2010



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