Caries Risk Factors for Primary Care Providers Based on Shared Determinants of Health

William Frese, MD, MPH
Arthur Nowak, DMD, MA
Leola Royston, MPH
Tanya Mathew, BDS, MS
Paul Casamassimo, DDS, MS
Robin Wright, PhD
Jan Silverman, MS, MSW, LCSW

Pediatric Oral Health Research & Policy Center

AMERICA'S PEDIATRIC DENTISTS
THE BIG AUTHORITY on little teeth®

Caries Risk Factors for Primary Care Providers Based on Shared Determinants of Health

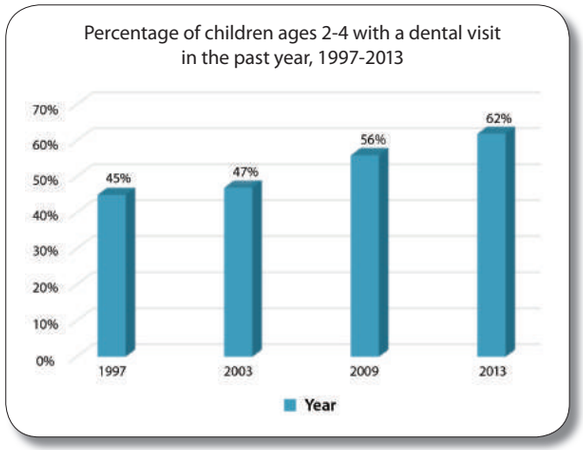
Introduction

A happy, healthy smile is vital to children – and invaluable to their parents. Unfortunately, poor oral health negatively affects many children, disrupting their physical and emotional development, school performance and behavior. In extreme cases, poor dental health and lack of treatment leads to serious disability and potentially life-threatening complications. In spite of the importance of oral health to overall health, most young children do not receive the benefits of an early dental visit, recommended by the American Academy of Pediatric Dentistry (**AAPD**) and the American Association of Pediatrics (**AAP**) at the time of the eruption of the first tooth and no later than 12 months of age.

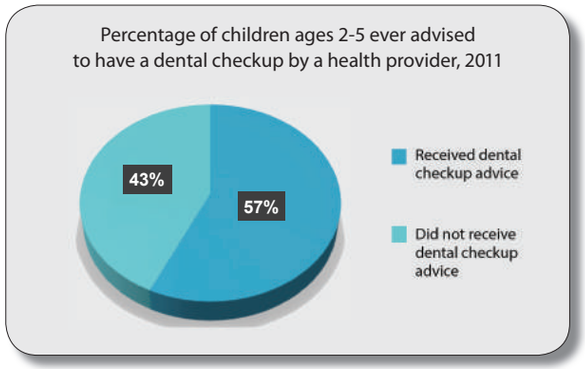
According to the American Dental Association Health Policy Institute, over 14 million children aged 1 to 4 years have visited a physician but not a dentist.[1] The AAP recommends primary care providers schedule children at least 13 times for well-child visits from birth through age 3 with the goal of providing risk assessment, prevention, disease identification, anticipatory guidance and referral for various health conditions to promote overall well-being.[2] Unfortunately, by the time many children have a dental visit, a majority of the behavioral and dietary risk factors for dental caries have long been established, such as habits related to oral hygiene and sugar consumption. Primary care providers can play a critical role in the prevention of dental caries and have a direct impact on the oral health status of young children.

Primary care providers are well positioned to reduce the impact of a wide variety of oral conditions. The AAP's policy statement on Preventive Oral Health Intervention for Pediatricians reinforces this conclusion: "A pediatrician who is familiar with the science of dental caries, capable of assessing caries risk, comfortable with applying various strategies of prevention and intervention, and connected to dental resources can contribute considerably to the health of his or her patients." However, only about half of pediatricians identify active caries or provide information on tooth-brushing.[3] The U.S. Preventive Services Task Force determined that, although more research is needed, inadequate evidence exists to demonstrate a positive impact on dental caries rates by physician-implemented oral health interventions.[4]

Early identification of children who are at high risk for dental caries by primary care providers indicates the need for a Caries-Risk Assessment (**CRA**) tool. Early CRA literature confirms the value of identification of caries as a reliable way to predict future caries.[5,6] Unfortunately, the use of existing CRA tools, which partly rely upon the presence of some level of dental disease for risk stratification, places the provider in the role of managing and controlling disease rather than preventing it.



Source: National Center for Health Statistics, National Health Interview Survey.[8]



Source: Center for Financing, Access, and Cost Trends, AHRQ, Household Component of the Medical Expenditure Panel Survey, 2011.[7]

Purpose

Beginning in 2014, the AAPD, along with the organizations represented by our advisory group,* began conducting a series of translational studies to explore pediatric medical providers' perceptions and practices surrounding oral health. Baseline data were gathered in focus groups and during practice observations with various primary care provider types and settings** in Year 1. These data indicated a need for a simple methodology, based primarily on key predictive risk factors identified in a general patient medical history, that can be implemented within the electronic health record (**EHR**). Almost all pediatric providers considered oral health screening and education an integral part of children's overall health, yet providers' adoption of available caries-risk assessment tools was low due to competing time demands at the well-child visit, limited clinical dental experience/education, and minimal reimbursement.

Current risk assessment tools, including the AAP's risk assessment tool, which is endorsed by a number of organizations, have a low adoption rate by medical practitioners. Surveys conducted during Year 1 of the project supported this observation. Only about one-third of medical personnel surveyed who conduct risk assessment were using the AAP tool. Rather, medical providers find it more practical to rely upon a wide variety of less formal risk assessments strategies, such visual inspection of the teeth. Our survey determined that a relatively large number of these informal and somewhat incomplete tools were developed by individual providers.

Given the inconsistent use of existing tools, and the limited amount of time during the well-child visit available for oral health, the logical next step in the investigation was to identify global variables collected routinely for all patients that might show a predictive relationship with dental disease.

> "This study supports the growing consensus of health research that different diseases share common risk factors. An easy-to-use decay-risk assessment based on information routinely gathered from the well-baby visit has the potential to engage primary care providers in oral health and encourage needed referrals for dental care."
>
> *~ Dr. Paul Casamassimo, Director, AAPD Pediatric Oral Health Research and Policy Center.*

A growing belief supported by recent research is that common social and behavioral risk factors shape various seemingly unrelated, chronic health conditions. Grabauskas explains, "Controlling a small number of risk factors may have a major impact on a large number of diseases at a lower cost, greater efficiency and effectiveness than disease-specific approaches."[9] The World Health Organization states, "Oral disease prevention and the promotion of oral health needs to be integrated with chronic disease prevention and general health promotion as the risks to health are linked."[10] Additionally, to close health disparity gaps, the common risk factor approach may be a more efficient solution than resources individually invested into isolated approaches

* Our advisory board was formed to provide guidance to the study design and execution. Members include: Lauren Barone, MPH (American Academy of Pediatrics Manager, Oral Health); Diane Dooley, MHS, MD (Chairperson of the Department of Pediatrics at Contra Costa Regional Medical Center); Erin Hartnett, DNP, APRN-BC, CPNP (NYU College of Nursing, Program Director, Oral Health Nursing Education and Practice (OHNEP), Teaching Oral-Systemic Health (TOSH)); Patrick Killeen, MS, PA-C (Past President, American Academy of Physician Assistants (AAPA), Leader of Special Interest Group on Oral Health for AAPA, Coordinator, PAs for Oral Health); Kim Kimminau, PhD (Research Director, American Academy of Family Physicians National Research Network, Associate Professor, Department of Family Medicine University of Kansas Medical Center); Tanya Mathew, BDS, MS (Nationwide Children's Hospital Assistant Research Professor Nationwide Children's Hospital); Diptee Ojha (American Dental AssociationSr. Manager, Office of Quality Assessment & Improvement Council on Dental Benefits Program).

** Provider types represented: pediatricians, family medicine physicians, nurse practitioners, physician assistants, pediatric residents, family medicine residents, registered nurses, licensed practical nurses, and medical assistants.

Settings include: public (such as academic medical centers, free clinics, and community health centers), private, HMOs, FQHCs, hospital based, school-based, and faith-based/volunteer.

Pediatric Oral Health Research & Policy Center

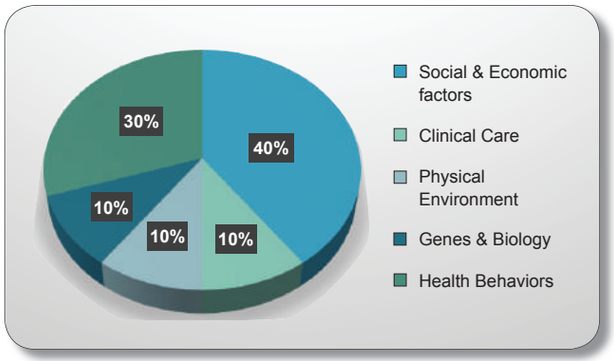
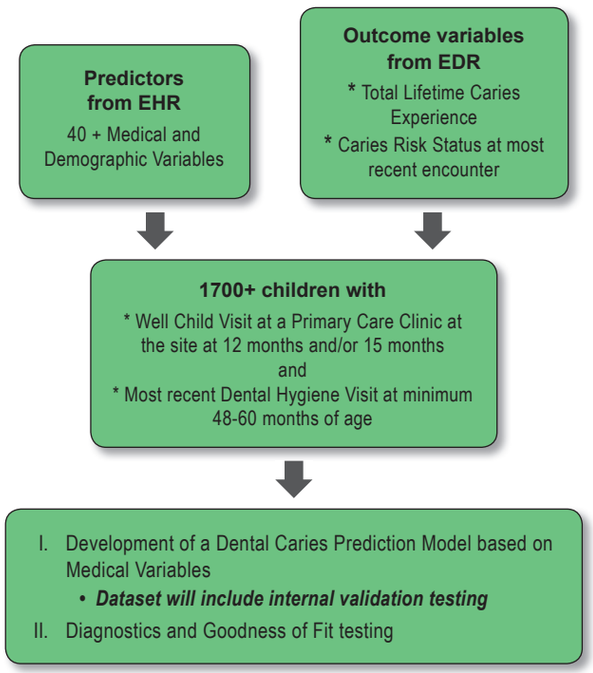


Figure 1. Estimation of the Relative Contribution of Multiple Determinants and Factors on Health Outcomes.

Source: An adaption. J. Michael McGinnis, Pamela Williams-Russo and James R. Knickman. The Case for More Active Policy Attention to Health Promotion. Health Affairs 21, no. 2 (2002):78–9312.



for oral health and other diseases.[11] This commonality is the basis for the project's direction with the aim of making oral health a seamless and integrated part of pediatric primary preventive medical care preventive care.

Figure 1 demonstrates the relative contributions of multiple determinants that impact health outcomes for a variety of health conditions. As primary care providers conduct detailed interviews and collect socio-demographic factors, the determinants and behaviors posing higher risk for dental caries may be easily identifiable.

The project was built around two main phases to best answer the project questions. First, health screening measures already intrinsic to the well-child encounter were explored in order to create a new history-based caries-risk screening tool that easily assimilates into the workflow of a well-child visit. (The identification of common risk factors not specifically based on current oral health status or behaviors lends itself to primary prevention). Second, to gauge provider interest in incorporating these common risk factors into medical providers' existing work flow, semi-structured interviews were conducted with pediatric health professionals to ascertain the most feasible construction of a caries-risk assessment tool within electronic health records (**EHR**).

Project questions:

1. Are there key predictive risk factors for dental caries that are routinely collected in the EHR during well-child pediatric care?
2. What is the feasibility of an EHR-based caries screening tool using available variables from the well-child visit?

Project aims of Year 2:

1. Identify global (common) risk factors from EHR that correlate to dental caries risk.
2. If significant factors are found, develop a prototype for a new, evidenced-based standardized CRA.
3. Conduct a survey of medical providers to assess the feasibility of integrating a new medically oriented CRA into well-child visit templates.

Methods

Nationwide Children's Hospital Data Analysis of Retrospective Chart Reviews

In 2015, a chart review to identify global, medical-specific factors that correlate to caries risk at Nationwide Children's Hospital (**NCH**) in Columbus, Ohio, was conducted. Since 2011, NCH has used an EpicCare Ambulatory EHR system (Epic Systems Corporation, Verona, Wis.) that fully integrates dental with general pediatrics and pediatric specialties. A cross-sectional analysis of NCH's electronic health system was conducted to identify children who had a 12-month or 15-month well-child visit or both, and at least one subsequent routine dental visit that included a comprehensive clinical examination and caries-risk assessment. A total of 1,736 patients met the criteria when a query was run in July 2015.

After consultation with the NCH Research Institute's Biostatistics Department to develop the study design and statistical plan, we determined that the dependent variables (or outcomes) were "lifetime caries experience" or "caries risk status." The Lifetime Caries Experience variable reflects a patient's lifetime experience of disease, and the Caries Risk Status variable reflects a convenient snapshot of the most recent caries risk assignment available on the NCH electronic health system.

- **Lifetime caries experience** was defined as the absence or presence of dental caries at the most recent dental encounter up to the time of the query. The presence of dental caries was defined as one or more teeth requiring restorative treatment for dental caries in a patient. It did not include patients with only white spot lesions and non-cavitated lesions that required no restorative treatment.

- **Caries risk status** was defined as the risk status designation given by the dental provider at the patient's most recent dental visit. The caries risk status variable was based on the most recent recording of dental caries risk using a CRA (Nationwide Children's Hospital Electronic CRA) that categorizes the patient as high, medium or low risk for dental caries at a visit, based on the provider's assessment of clinical and behavioral risk factors. It is independent of previous ratings for risk status. Medium and Low Risk patients were combined as "not high risk" patients. Thus, the study population was divided into two groups, "not high risk" and "high risk."

The next step in study development was to identify all potential risk variables in the medical record that may correlate with dental caries or other determinants of health. A listing of variables and diagnoses pertaining to nutrition, safety, development, demographics, complex medical disease, referrals to medical specialists, and other factors already embedded within the 12- and 15-month well-child examination templates that could be easily searched and extracted from the EHR were generated. This resulted in hundreds of identified variables. Given

Table 1. VARIABLES OF INTEREST

#	Medical Variable from EHR
A	**Demographics & Miscellaneous**
1	Age of Child at 12 month/15 month/18 month Well Child Visit
2	Gender
3	Racial group
4	Ethnicity
5	Zip code
6	Single Parent Household
7	Religion
8	Language
9	City
10	Interpreter use at 12 /15/18 months
B	**Examination & History**
11	Weight
12	Head circumference, normal or not
13	BMI, normal or not
14	Birth History - gestation age only
15	Past Medical history
16	History of hospitalizations
17	Exposure to Second Hand Smoke
18	Speech Difficulty
19	History of allergies
20	Prescriptions
21	Health problem list
22	ICD -9 code(s) of medical diagnosis (especially if dentally relevant)
23	Dental Varnish applied?
24	Dental counseling given?
	Developmental Screening
25	Screening results for 12 month, 15 month and 18 month well child visits
26	Was a referral made to a medical specialist?
27	Developmental delay?
	Dietary Factors
28	Appropriate for age
29	Poor diet
30	High sugar diet
31	Breastfeeding at 12 /15/18 months

Table continued on next page

Table 1. CONTINUED

#	Medical Variable from EHR
32	ICD9 codes related to abnormal diet or nutritional problems
33	Bottle or sippy cup use
34	Eating habits at 12 /15/18 months
	Lab Reports
35	Abnormal Iron Screening Results from Well Child Visits
36	Abnormal Lead Screening Results from Well Child Visits
	Sleep Pattern
37	Appropriate for age
38	Nighttime feeding habit
39	Sleep disturbances
	Financial/Poverty Information
40	Type of insurance - Medicaid, commercial, self-pay
41	Zip code
	Parent Compliance Measure
42	Broken appointment rate in %
43	Timely vaccination history, up to date or not at 18 months of age
44	Age of child at corresponding Well Child Visit

#	Dental Variable from EHR/EDR
45	Age at first dental visit
46	Age at most recent dental visit
47	Total number of teeth needing restorations or extractions due to dental caries
48	Caries Risk Assessment results at most recent dental visit
49	Mother has untreated dental caries
50	Types of drinks in bottle/sippy/regular cup
51	How often are teeth brushed?
52	What time of day are child's teeth brushed?
53	Does child cooperate while brushing?
54	What type of toothpaste is used when brushing child's teeth?
55	Source of drinking water and whether fluoridated
56	Does child drink at nap and/or night (includes nursing)?
57	Number of times a day child snacks

the overriding aim of this project to produce a more simplified caries risk assessment, this extensive list was further quantitatively and qualitatively reduced. Criteria included frequency of provider entry, scientifically known or suspected caries associations, and consistency of appearance across both the 12- and 15-month well-child templates, resulting in a more manageable list of approximately 40 independent variables to be considered (see Table 1).

The IT Data Warehouse staff, Research Data Computing staff and IT support staff reviewed the list of 40 independent variables. A thorough analysis was conducted to determine whether the variable was available as discreet data and whether it would be possible to extract the variable for analysis. Since documentation templates used in the primary care clinics at NCH were not completely configured for electronic data collection, some important variables were not extractable from the EHR.

Several variables in the primary care clinic templates for well-child visits were difficult to extract. Retrospective chart reviews are inherently fraught with challenges due to missing documentation by providers in fields relevant to the project. For example, breastfeeding was not included within the well-child template, but the information was documented in the medication review section. Caries status of the mother was not routinely collected at well-child visits, but due to its significance, the variable was extracted from the dental record and used for analysis. In addition, the well-child template lacked questions related to sugar content in the diet or frequency of sugar consumption, invaluable information to determine risk for dental caries. This information was extracted from dental records in keeping with project goals and future development of a new caries risk assessment tool.

Results from the dental and medical extractions were then combined and submitted for statistical analysis. This step involved further data clarification for several variables. Each variable that had more than one response needed to be reclassified as "yes" or "no." For example, any child referred to one or more specialists was reclassified as "yes" rather than a numerical value. Numerical results of lead levels were reclassified as normal or abnormal. Similarly, zip code data was relabeled based on census data as "high poverty" or "not high poverty" zip codes. City data from the address of the child was classified into "greater Columbus" and "not greater Columbus." Since racial and ethnicity data offered 120 choices and was self-reported by the parent with the option of "prefer not to disclose," the data was reviewed individually and reclassified as "Hispanic" and "non-Hispanic" as well as "Black" and "non-Black." The frequency distribution of each variable was calculated, and data was analyzed.

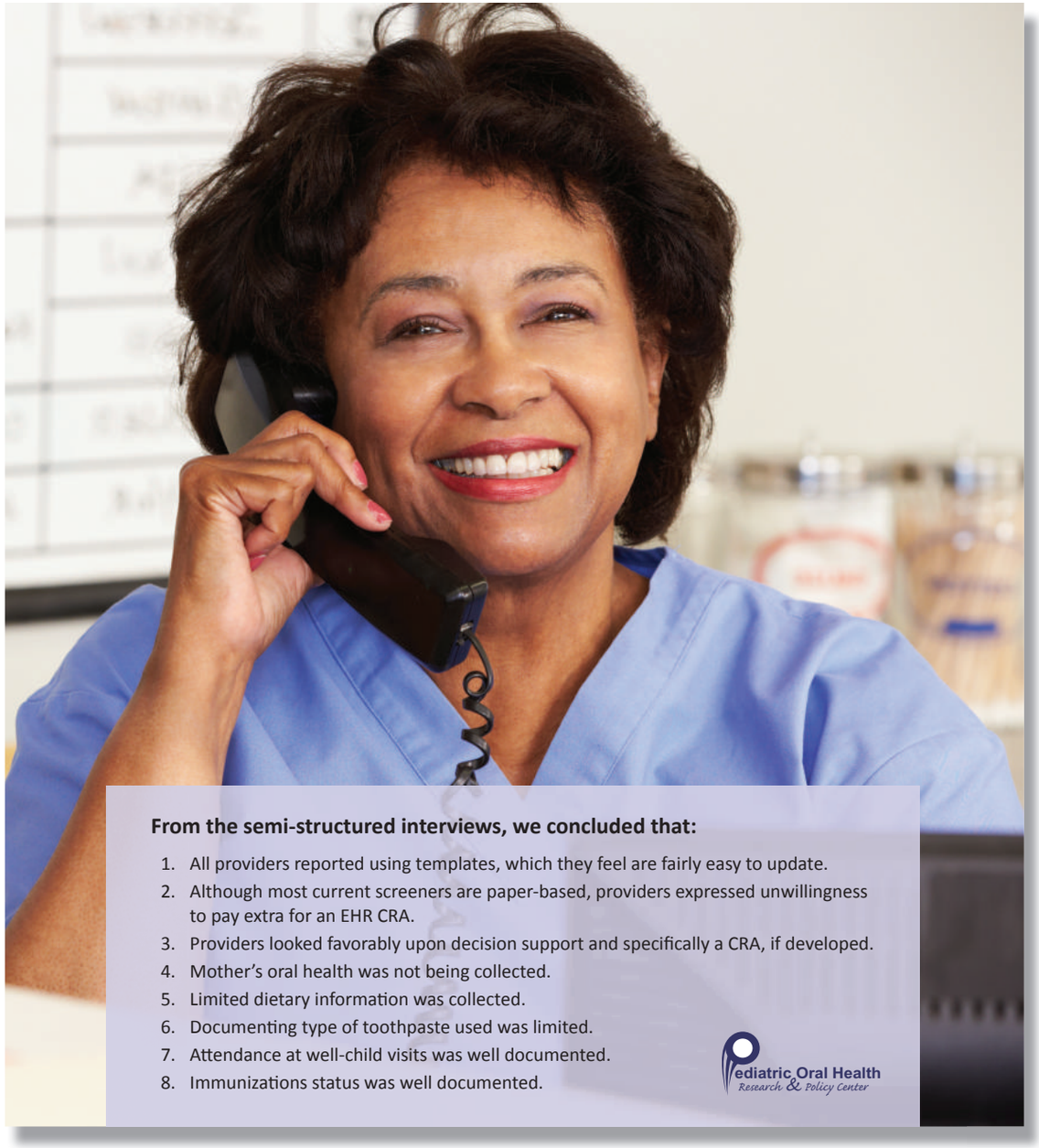
Univariate analyses were performed to determine the association between each medical variable and each of the two dental outcomes. For continuous variables, the comparisons were performed using Wilcoxon rank-sum test. For categorical variables, comparisons were performed using Pearson's chi-square test. All tests were two-sided at a significance level of 0.05. Statistical analysis was performed using SAS Version 9.3. Univariate analyses compared each independent medical variable to the "caries" versus "no caries" groups, as well as the "high risk" versus "not high risk" groups.

Semi-Structured Interviews

In addition to data analyses at NCH for the retrospective chart review, semistructured interviews with pediatric health professionals who also participated in the Year 1 project were completed.* Moderators conducted approximately one-hour semi-structured telephone interviews with site-selected oral health champions and/or liaisons from sites that participated in a previous project. During each interview, the moderator followed a guided series of questions related to EHRs, screening and decision support, and thoughts and opinions of an electronic caries screening tool.

* Provider types represented: three family physicians, four pediatricians, one physician assistant.

Settings included: university based, private, and FQHC.



From the semi-structured interviews, we concluded that:

1. All providers reported using templates, which they feel are fairly easy to update.
2. Although most current screeners are paper-based, providers expressed unwillingness to pay extra for an EHR CRA.
3. Providers looked favorably upon decision support and specifically a CRA, if developed.
4. Mother's oral health was not being collected.
5. Limited dietary information was collected.
6. Documenting type of toothpaste used was limited.
7. Attendance at well-child visits was well documented.
8. Immunizations status was well documented.

Pediatric Oral Health Research & Policy Center

Results

Nationwide Children's Hospital Data Analysis of Retrospective Chart Reviews

Population Characteristics. Population characteristics on the 1,736 children who met the criteria for both early well-child visits and dental visits is summarized below.

- The **gender** of the subject pool was 46 percent female and 54 percent male.
- The **average age** for children at the 12-month well-child visit was 12.6 months, and the average age for the 15-month well-child visit was 15.9 months.
- The **average age** for the Dental Caries Experience Evaluation was 40 months of age, with ages ranging from 15 months to 78 months at the most recent dental examination.
- Regarding **race and ethnicity**, the study population consisted of a variety of racial and ethnic groups, representative of the NCH patient population.

The study population self-reported that they belonged to 48 out of 120 possible ethnic groups; 44 percent identified themselves as "American." With respect to the primary language spoken by the patient families, 61 percent spoke English and the remaining 39 percent spoke 33 different languages ranging from Albanian to Zomi. The total number of cities of residence was 55, re-classified as either Greater Columbus (95 percent) or outside the Greater Columbus area. A total of 2,921 ICD-9 codes of medical conditions were analyzed and narrowed to a list of 237 codes for the 12-month well-child visit and 215 codes for the 15-month well-child visit as "dentally relevant." Approximately 25 percent of the patients had 6 or more broken appointments (see Table 2).

"These results are valuable because the discovered decay-risk variables are already a part of the well-baby visit. Oral health screening can more efficiently be incorporated into the visit, an advantage not only for primary care providers, but for busy parents and active toddlers."

~ Dr. William Frese, Principal Investigator, Assistant Professor of Pediatrics, University of Illinois Hospital.

Statistical Analysis of Variables based on Lifetime Caries Experience. The dependent variable of lifetime caries experience was dichotomized into "caries" versus "no caries." Among 1,736 study subjects, 523 had caries, 1,180 did not have caries, and 33 had missing data. For the univariate analysis, each independent variable was compared between the "caries" and "no caries" group. The variables with shown significance are potential predictors in the final predictive logistic regression model (see Table 3).

Table 2. POPULATION CHARACTERISTICS

Characteristics	%
Male gender	54
Race	
Hispanic	8
Black	17
Zip code with >20% living below federal poverty line	31
Fluoridated water in community	99
Mother has active caries	22
Life history of broken appointments	25
Immunizations not up to date (12 and 15 months)	8, 9
Breast milk (12 and 15 months)	12, 6.5

Table 3. VARIABLES WITH SIGNIFICANT ASSOCIATIONS WITH CARIES OUTCOME AND RISKS (N=1,736)

Significant variables using lifetime caries experience as the outcome variable	*p*-value	Significant variables using caries risk status assigned at the most recent dental encounter as the outcome variable	*p*-value
Being Hispanic	0.0338	ZIP code with high poverty >20% of population	0.0034
Referral to MD specialist at 12 months	<.0001	Drinking at nap/ sleep times	0.0414
Immunizations not up to date at 15 months	<.0001	Mothers have untreated caries*	0.0152
Breast milk at 15 months	0.0095	Breast milk at 12 & 15 months	0.0296 & 0.0331
History of broken appointments	0.0007	Immunizations not up to date	<.0001
		History of broken appointments	0.0002
		Medicaid insurance at 15 months	0.0484

** Collected from Dental EHR data.*

Statistical Analysis of Variables Based on Caries Risk Status. The dependent variable of caries risk status was dichotomized into "high risk" versus "not high risk." Among 1,736 study subjects, 505 were designated as "high risk," 1,187 as "not high risk," and 44 had missing data. For the univariate analysis, each independent variable was compared between the "high risk" group and "not high risk" group. Those showing significance are possible predictors in the final logistic regression model (see Table 3).

In addition to well-known predictors of infant's caries risk, such as a history of nighttime feedings, family income level and the primary caregiver's oral health status, novel associations not previously included in other formalized caries-risk screeners and more specific to the medical encounter were discovered. These predictors were delayed immunizations status, prolonged breastfeeding beyond 12 months, and poor utilization of preventive medical care.

Semi-Structured Interviews

Interview objectives were to gain feedback on the most useful, feasible construction of an EHR-based caries-risk assessment tool for medical providers. Interview questions were broken into three sections: General EHR, EHR screening and decision support, and caries-screening tools.

General EHR. When asked general questions about their EHR systems, no predominant brand of EHR was identified. Providers did report using templates for well-child exams, mainly procured "off the shelf." When asked about the ease or difficulty of making changes to their EHR systems, providers stated that changes were fairly easy and made routinely, accompanied by timely updates.

EHR Screening and Decision Support. In the section on EHR screening and decision support, the goal was to gather information about the current functions of participants' EHRs. Providers reported that paper-based and electronic screeners were being used, such as the "Ages and Stages Questionnaire" and "Modified Checklist for Autism in Toddlers." Generally, someone other than the primary care provider completed the screenings, including front desk staff, medical assistants and nurses. When asked if their EHR or well-child exam templates currently included any decision support, providers reported clinical decision-making support for drug interactions and allergies. Nearly all providers rated their decision-making support as somewhat helpful, and nearly all felt it positively influenced their care plans.

Caries-Screening Tool. The final section of questions focused on the specific variables found to be statically significant for caries risk through the data analysis conducted at NCH, whether provider's EHRs collected this information, and opinions on a self-scoring caries-risk assessment. When asked about a hypothetical screening tool, provider response was positive, with all rating their willingness to use such a tool if it were available as likely to very likely. Willingness to purchase such a tool if not included as a standard part of providers' EHR varied from likely to not likely (see Table 4).

Table 4. DOES YOUR CURRENT [12/15 MONTH OLD SPECIFIC] WELL CHILD EXAM TEMPLATE OR EHR SYSTEM OVERALL INCLUDE THE FOLLOWING SCREENING QUESTIONS OR INFORMATION?*

Question	% responded in the affirmative	Notes
Ethnicity demographic information.	80	
Any indicators of socioeconomic status/poverty via zip code of residence or insurance status (i.e. Medicaid)—likely in EHR demographics info section.	100	Indirectly represented by insurance and zip code information. Insurance information probably more representative of income than zip code, especially in smaller communities.
Information pertaining to/that tracks the patient's visit show-rate.	100	Records track this, but not necessarily available without searching.
Specific screening question inquiring about mother's oral health status.	0	
Specific dietary screening question asking about nighttime feeding (bottle or nursing).	40	Questions are more general about overall nutrition.
Specific dietary question about whether child is still nursing versus milk intake at 12 and 15 months of age.	100	
Determination/documentation of whether child's immunization status is up to date vs. delayed at 12 and 15 months of age via quality improvement reporting system in EMR, or ICD-9.	80	Information is not necessarily integrated into the EHR. Could feature simply a yes or no rather than an exhaustive list of specific immunizations.
Specific documentation of whether the child specifically is using fluoridated toothpaste or not.	40	Not a critical variable at this point, may become important based on further validation.
Determination/documentation of any required lead testing status being complete/UTD via specific question documentation or EMR labs review.	80	

** Question based off significant CRA variables discovered though NCH data analysis.*

Discussion

Nationwide Children's Hospital Data Analysis of Retrospective Chart Reviews

Dental disease, one of the most prevalent chronic diseases of childhood, shares multifactorial causes with other chronic diseases, such as obesity, infection and atopic illnesses, asthma, allergies, and developmental/behavioral concerns. The two most significant variables identified by our data using lifetime caries experience as the outcome variable were:

1. Referral to a MD specialist at 12 months ($p<.0001$).
2. Immunizations not up to date at 15 months ($p<.0001$).

Other significant factors included being Hispanic ($p=.03$), breast milk at 15 months ($p=.01$), and a history of broken appointments ($p=.001$).

Factors that were significantly related to caries-risk status at the most recent dental encounter included a home zip code with high poverty as more than 20 percent of the population (.03), drinking at nap/sleep times (.04), breast milk at 12 and 15 months (.02 and .03), mothers' own poor oral health status (.02), immunizations not up to date (<.0001), and a history of broken appointments (.0002).

Referral to an MD specialist at 12 months. Referral to an MD specialist at 12 months indicates a child has a need for specialized medical services, which may be a surrogate measure of special healthcare needs (**SHCN**). Scientific literature links SHCN with an increased incidence of dental disease. This holds true for those with intellectual disabilities[13], systemic disease[14], developmental disabilities[15], and children who used systemic antibiotics during the first year of life or long-term liquid medications[16,17]. In fact, dental care remains the most frequently cited unmet health need for children with SHCN.[18]

Immunizations not up to date at 15 months and a history of broken appointments. There is a direct relationship between delayed immunizations and defaulted well-child visits. Interestingly, a lack of adequate prenatal care is a strong predictor of delayed immunizations in the child.[19] Literature identifies parent-related factors, such as having a sick child, a lack of parental memory, and a fear of side effects as being associated with both delayed immunization status and defaulted appointments.[20] Given our common risk factor approach and significant findings, it is not unreasonable to believe there also is a significant association with these same parent-related factors and caries development as well. Further related, parental social issues have been identified as the most cited barrier to immunization, as well as a lack of parental education about preventive health care.[21]

Breast milk at 15 months and drinking at nap/sleep times. A 2007 study from the 1999–2002 National Health and Nutrition Examination Survey found no evidence to suggest that breastfeeding or its duration are independent risk factors for early childhood caries, severe early childhood caries, or decayed and filled surfaces on primary teeth.[22] However, while breast milk alone may

not be cariogenic[23,24], ad libitum breastfeeding after the introduction of carbohydrates has been implicated in early childhood caries.[25] The risk of caries increases when sugars are ingested frequently (snacking) and remain in the mouth for extended periods, such as feeding at nap/sleep times.[26]

Mother's poor oral health status. Mothers' oral health status is a strong predictor of the oral health status of their children. Transmission of mutans streptococci from parents and caregivers to children has long been tied to increased rates of caries in children.[27–29] Additionally, parental dental hygiene habits may influence their children's oral health.[30] Data for this variable were collected from dental health records, since adoption of this as a caries screening variable in the medical setting has not been universal. Given that a mothers' health status is such a reliable marker of children's oral health status, its incorporation into medical screening measures is strongly recommended.

Zip code with high poverty in over 20 percent of the population. It is well documented that children from low-income and minority families have poorer oral health outcomes, fewer dental visits, and fewer protective sealants. Children from low-income families suffer twice as much from dental caries as children from more affluent families.[31] In one study, approximately half of those in lower-income groups experienced dental caries compared to only a third of children from families with incomes at or below 200 percent of the federal poverty level.[32] Utilization of dental services is also lower among low-income families.[33] Among children aged three to five living in poverty, approximately one in four had untreated dental caries compared to one in ten in those living above the poverty level.[34] All of our interview participants indicated that their EHR collects information about either zip code or Medicaid insurance that can be correlated to low-income status, suggesting poverty status could easily be incorporated into an EHR-based CRA.

Hispanic ethnicity. The greatest racial and ethnic oral health disparity among children aged two to four years and aged six to eight years is seen in Mexican American and black, non-Hispanic children.[35] Hispanic children are also less likely than the general population to have dental visits. Research suggests that Hispanic parents may lack dental insurance and hold beliefs that professional dental care is not important if one takes care of the teeth.[36] Similar to the above poverty status, a majority of our interview participants affirmed that their EHR collects information on this variable that can be applied towards CRA construction.

Both outcome variables hold merit to the assessment of caries risk. The lifetime caries experience variable is based on actual evidence and advancement of disease. However, the assigned high-risk status of patients may suggest a persistence of risk factors over time, and therefore may indicate a higher level of risk.

The study also demonstrates the inherent challenges presented by retrospective data collection from an EHR. Due to missing data and incomplete records, the sample was not large enough

to conduct a multiple regression analysis for the creation of a caries prediction model. However, the lessons learned were instrumental in designing a robust feasibility analysis process to select a site for Year 3 and increase the study population.

Semi-Structured Interviews

The interviews indicated a high level of provider interest in a medically specific caries-risk assessment tool and further supported that these significant variables already exist in providers' EHRs. Not only did most providers report that they had the variables in their EHRs, but that the variables were searchable "point and click" data fields by the EHR. This suggests that providers' EHRs are generally well-poised to build an EHR-based caries-risk assessment tool.

Providers also indicated a strong interest in an automatic decision-support system that uses this information to indicate caries risk. They considered this approach a practical solution for improving the engagement and participation by primary care providers in early oral health screening and referrals. As stated by one provider, "I think that (a caries-risk automatic decision support system) becomes, especially for a parent that doesn't necessarily have the best dental coverage, a talking point. Your child stands out as somebody different than everybody else. This isn't just a routine recommendation of 'go to the dentist.' I'm telling you I've identified risks. I do think that would hold value in lots of different planes."

Additionally, participants reiterated the concept of all medical staff working at the top of their paygrade, and the possibility of such a tool being utilized by members of the medical staff other than the primary care provider. "Many practices are embracing this lean concept, making sure that the right work is being done at the right place at the right time by the right people."

"I think that (a caries-risk automatic decision support system) becomes, especially for a parent that doesn't necessarily have the best dental coverage, a talking point. Your child stands out as somebody different than everybody else. This isn't just a routine recommendation of 'go to the dentist.' I'm telling you I've identified risks. I do think that would hold value in lots of different planes."

~ Semi-Structured Interview Participant.

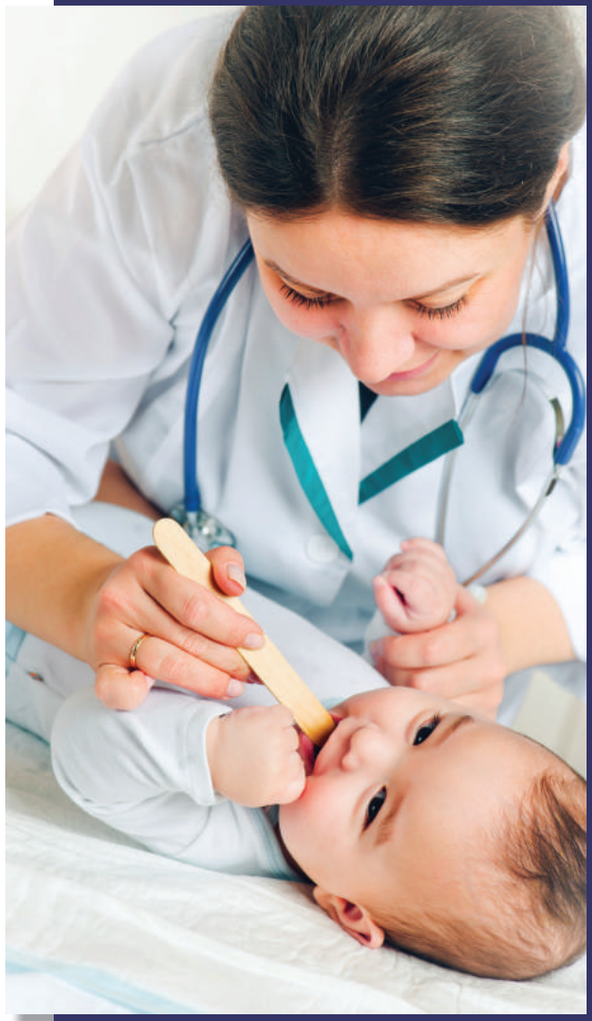
Study Limitations

The study has limitations prompting careful interpretations of some of the findings. First, as in most empirical studies, the research presented here was limited by the measures used. Telephone interviews rely on participants' ability to recall information on the spot. Additionally, interviewers are not able to pick up on nonverbal cues. Sample size and complexity of questions are also restricted. Electronic health and dental record review presents limitations in regard to generalizability of results as well as varying degrees of incomplete data entry by users. We used outcome variables that were most practical based on available data fields. Perhaps another EHR-EDR combination would allow different outcome measures.

Second, our data analysis was cross-sectional in nature and assessed caries-risk status and caries experience at a specific point in time; it can only demonstrate associations and not causality. Third, our study did not examine the impact that the individual variables may have on one another. Fourth, because the sample was restricted to 1,736 eligible patients at Nationwide Children's Hospital, the results of this study may not be completely generalizable to other child patient populations.

Looking Ahead

The next phase of the study will further validate the medical factors identified as correlating to caries risk – and explore other potentially significant variables – through an analysis of electronic medical and dental records of additional U.S. child populations. In addition, a caries-prediction tool will be developed after further clarifications of predictors. If successful, it will be pilot tested at NCH. A caries-risk assessment based on information routinely gathered from well-baby visits is very promising for preventing Early Childhood Caries. Necessary dental referrals and oral health education may be delivered more efficiently and much earlier by primary care providers at well-baby visits. This in turn could lead to more interprofessional collaboration and integrated models of care.



Conclusion

Oral health impacts overall health and quality of life. Primary care providers recognize the importance of oral health, but many have found it difficult to adopt oral health screening protocols in their practices for a myriad reasons. The common risk factor approach may be a method to identify the global variables collected routinely for all patients that show a predictive relationship with dental disease. The aim of this study was to identify health screening measures intrinsic to the recommended well-child visit that might relate to caries risk.

> "A dental referral by a child's first birthday is particularly critical to a child's oral health, especially when factors associated with risk for tooth decay are present. The value of a Dental Home early in life is demonstrated in both clinical data and children's smiles."
>
> *~ Dr. Arthur Nowak, Principal Investigator, Fellow, AAPD Pediatric Oral Health Research and Policy Center.*

The new risk factors for caries identified in this analysis are standard parts of well-child care that medical pediatric providers are adept at asking, and require little or no additional data input above baseline well-child screening measures. The next steps toward improving provider adherence to oral health screening at well-child visits are to incorporate these variables into a new medically-specific caries-risk assessment tool within the EHR. Easier oral health screenings, prompting earlier referrals of young children to a Dental Home, will help provide access to preventive dental services to those children most at risk for dental problems.

About the American Academy of Pediatric Dentistry

The American Academy of Pediatric Dentistry is the recognized authority on children's oral health. As advocates for children's oral health, the AAPD promotes evidence-based policies and clinical guidelines; educates and informs policymakers, parents and guardians, and other health care professionals; fosters research; and provides continuing professional education for pediatric dentists and general dentists who treat children. Founded in 1947, the AAPD is a not-for-profit professional membership association representing the specialty of pediatric dentistry. Its 9,900 members provide primary care and comprehensive dental specialty treatments for infants, children, adolescents and individuals with special health care needs. The Pediatric Oral Health Research and Policy Center (**POHRPC**) helps the AAPD be more effective in the public policy arena by analyzing data, research, and policy and carrying out health services research that can have a positive impact on children's oral and overall health. For further information, visit the AAPD website at: ***http://www.aapd.org*** or the AAPD's consumer website at: ***http://www.mychildrensteeth.org.***

This study was supported through grants from the DentaQuest Foundation.

References

1. Vujicic M, Israelson H, Antoon J, Kiesling R, Paumier T, Zust M. A profession in transition. J Am Dent Assoc 2014;145(2):118-21. doi:10.14219/jada.2013.40.
2. Lewis CW, Boulter S, Keels MA, et al. Oral Health and Pediatricians: Results of a National Survey. Acad Pediatr 2009;9(6):457-61. doi:10.1016/j.acap.2009.09.016.
3. Committee on Practice and Ambulatory Medicine and, Bright Futures Periodicity Schedule Workgroup. 2016 Recommendations for Preventive Pediatric Health Care. Pediatrics 2016;137(1):1-3. doi:10.1542/peds.2015-3908.
4. Moyer VA. Prevention of Dental Caries in Children From Birth Through Age 5 Years: US Preventive Services Task Force Recommendation Statement. Pediatrics 2014;133(6):1102-11. doi:10.1542/peds.2014-0483.
5. Bader JD, Graves RC, Disney JA, et al. Identifying children who will experience high caries increments. Community Dent Oral Epidemiol 1986;14(4):198-201.
6. Paunio P, Rautava P, Helenius H, Alanen P, Sillanpää M. The Finnish Family Competence Study: The Relationship between Caries, Dental Health Habits and General Health in 3-Year-0ld Finnish Children. Caries Res 1993;27(2):154-60.
7. Soni A. Children's Dental Care: Advice and Visits, Ages 2–17, 2011. Statistical Brief #432. Agency for Healthcare Research and Quality, Rockville, MD. Available at: http://meps.ahrq.gov/mepsweb/data_files/publications/st432/stat432.shtml.
8. Childstats.gov. HC4.A/B Oral Health: Percentage of Children Ages 2-17 with a Dental Visit in the Past Year by Age and Selected Characteristics, 1997–2013. National Health Interview Survey. National Center for Health Statistics. Available at: http://www.childstats.gov/americaschildren/tables/hc4ab.asp.
9. Grabauskas V, Leparski E. Integrated programme for community health in non communicable disease (Interhealth). Prev Non Commun Dis Exp Prospects Cph WHO Reg Off Eur. 1987.
10. Petersen PE. World Health Organization global policy for improvement of oral health-World Health Assembly 2007. Int Dent J 2008;58(3):115-21.
11. Sheiham A, Watt RG. The common risk factor approach: a rational basis for promoting oral health. Community Dent Oral Epidemiol 2000;28(6):399-406.
12. McGinnis JM, Williams-Russo P, Knickman JR. The case for more active policy attention to health promotion. Health Aff (Millwood) 2002;21(2):78-93.
13. Anders PL, Davis EL. Oral health of patients with intellectual disabilities: a systematic review. Spec Care Dentist 2010;30(3):110-7.
14. Thikkurissy S, Lal S. Oral health burden in children with systemic diseases. Dent Clin North Am 2009;53(2):351-7.
15. Charles JM. Dental care in children with developmental disabilities: attention deficit disorder, intellectual disabilities, and autism. J Dent Child 2010;77(2):84-91.
16. Alaki SM, Burt BA, Garetz SL. The association between antibiotics usage in early childhood and early childhood caries. Pediatr Dent. 2009;31(1):31-7.
17. Walimbe H, Bijle MNA, Nankar M, Kontham U, Bendgude V, Kamath A. Knowledge, Attitude and Practice of Paediatricians toward Long-Term Liquid Medicaments Associated Oral Health. J Int Oral Health JIOH 2015;7(1):36.
18. Lewis CW. Dental care and children with special health care needs: a population-based perspective. Acad Pediatr 2009;9(6):420-6.
19. Feemster KA, Spain CV, Eberhart M, Pati S, Watson B. Identifying infants at increased risk for late initiation of immunizations: maternal and provider characteristics. Public Health Rep 2009:42-53.
20. Thomas M, Kohli V, King D. Barriers to childhood immunization: findings from a needs assessment study. Home Health Care Serv Q 2004;23(2):19-39.
21. Milteer RM, Jonna S. Parental reasons for delayed immunizations in children hospitalized in a Washington, DC, public hospital. J Natl Med Assoc 1996;88(7):433.
22. Iida H, Auinger P, Billings RJ, Weitzman M. Association between infant breastfeeding and early childhood caries in the United States. Pediatrics 2007;120(4):e944-e952.
23. Erickson PR, Mazhari E. Investigation of the role of human breast milk in caries development. Pediatr Dent 1999;21:86-90.
24. Mohebbi SZ, Virtanen JI, Vahid-Golpayegani M, Vehkalahti MM. Feeding habits as determinants of early childhood caries in a population where prolonged breastfeeding is the norm. Community Dent Oral Epidemiol 2008;36(4):363-9.
25. Feldens CA, Giugliani ERJ, Vigo A, Vítolo MR. Early feeding practices and severe early childhood caries in four-year-old children from southern Brazil: a birth cohort study. Caries Res 2010;44(5):445-52.
26. Tinanoff N, Palmer CA. Dietary determinants of dental caries and dietary recommendations for preschool children. J Public Health Dent 2000;60(3):197-206.
27. Davey AL, Rogers AH. Multiple types of the bacterium *Streptococcus mutans* in the human mouth and their intra-family transmission. Arch Oral Biol 1984;29(6):453-60.
28. Berkowitz RJ, Jones P. Mouth-to-mouth transmission of the bacterium *Streptococcus mutans* between mother and child. Arch Oral Biol 1985;30(4):377-9.
29. Douglass JM, Li Y, Tinanoff N. Association of mutans streptococci between caregivers and their children. Pediatr Dent 2008;30(5):375-87.
30. Mattila M-L, Rautava P, Sillanpää M, Paunio P. Caries in five-year-old children and associations with family-related factors. J Dent Res 2000;79(3):875-81.
31. Health UD of, Services H, others. Oral health in America: a report of the Surgeon General. Rockv MD US Dep Health Hum Serv Natl Inst Dent Craniofacial Res Natl Inst Health 2000;63:74-94.
32. Dye BA, Tan S, Smith V, et al. Trends in oral health status: United States, 1988-1994 and 1999-2004. Vital Health Stat 11 2007;(248):1-92.
33. US NC for HS, others. Health, United States, 2011: With special feature on socioeconomic status and health. 2012. Available at: http://www.ncbi.nlm.nih.gov/pubmed/22812021. Accessed April 8, 2016.
34. Dye BA, Li X, Thornton-Evans G. Oral Health Disparities as Determined by Selected Healthy People 2020 Oral Health Objectives for the United States, 2009–2010 [Internet]. Hyattsville (MD): National Center for Health Statistics; 2012 [cited 2014 Oct 16].
35. CDC. CDC - Disparities in Oral Health - Division of Oral Health. Available at: http://www.cdc.gov/oralhealth/oral_health_disparities/index.htm. Accessed December 1, 2015.
36. GfK Roper Public Affairs & Corporate Communications. Hispanics Open Up About Oral Health Care. A Collaboration Between the Hispanic Dental Association (HDA), Crest and Oral-B. November 2011. Available at: http://www.dentalcare.com/media/en-US/events/HDA-MiniReport-English_10-27-11.pdf. Accessed December 1, 2015.

Pediatric Oral Health Research & Policy Center

AMERICA'S PEDIATRIC DENTISTS

THE BIG AUTHORITY on little teeth®

Pediatric Oral Health Research & Policy Center