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# Influences on Children's Oral Health: A Conceptual Model

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## ABSTRACT

**OBJECTIVES.** Despite marked improvements over the past century, oral health in America is a significant problem: caries is the most common chronic disease of childhood. Much oral health research examines influences primarily in the oral cavity or focuses on a limited number of individual-level factors. The purpose of this article was to present a more encompassing conceptual model of the influences on children's oral health.

**METHODS.** The conceptual model presented here was derived from the population health and social epidemiology fields, which have moved toward multilevel, holistic approaches to analyze the complex and interactive causes of children's health problems. It is based on a comprehensive review of major population and oral health literatures.

**RESULTS.** A multilevel conceptual model is described, with the individual, family, and community levels of influence on oral health outcomes. This model incorporates the 5 key domains of determinants of health as identified in the population health literature: genetic and biological factors, the social environment, the physical environment, health behaviors, and dental and medical care. The model recognizes the presence of a complex interplay of causal factors. Last, the model incorporates the aspect of time, recognizing the evolution of oral health diseases (eg, caries) and influences on the child-host over time.

**CONCLUSIONS.** This conceptual model represents a starting point for thinking about children's oral health. The model incorporates many of the important breakthroughs by social epidemiologists over the past 25 years by including a broad range of genetic, social, and environmental risk factors; multiple pathways by which they operate; a time dimension; the notion of differential susceptibility and resilience; and a multilevel approach. The study of children's oral health from a global perspective remains largely in its infancy and is poised for additional development. This work can help inform how best to approach and improve children's oral health.

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### Key Words

oral health, population health, pediatrics

### Abbreviation

DMFT—decayed, missing, or filled permanent teeth

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WITH LARGE-SCALE IMPROVEMENTS in sanitation, nutrition, fluoridation, and access to dental care, the oral health of Americans has improved markedly over the past century,<sup>1-4</sup> including substantial declines in children's dental caries prevalence<sup>2</sup> and the proportion of untreated caries in the permanent dentition of school-aged children.<sup>5</sup> Since the late 1940s, improved oral health has been largely attributable to increased access to fluoride via water and dentifrices by a large proportion of the population, yet caries remains the most common chronic disease in children.<sup>2</sup> Identifying other methods to further reduce oral health problems requires a more comprehensive understanding of factors influencing children's oral health.

Population health research during the past 3 decades has focused on describing medical and nonmedical determinants of health.<sup>6-14</sup> A growing, parallel body of work has centered on identifying the dental and non-dental determinants of adult and children's oral health.<sup>15-18</sup> This work offers a basis on which to develop a conceptual model of children's oral health determinants. This model provides structure identifying genetic and biological factors, social and physical environment, health behaviors, and dental and medical care influencing children's oral health outcomes at individual, family, and community levels. The purpose of this multidimensional, multilevel conceptual model is to stimulate discussion about determinants of children's oral health from a population health perspective. The model supplies a framework for research, for policy-making, and for more effective resource allocation to improve children's oral health.

### CONCEPTUALIZATION OF INFLUENCES ON CHILDREN'S ORAL HEALTH

Historically, researchers focused on biological and dietary influences. In recent years, interest has grown in exploring children's oral health outcomes using a broader framework, incorporating psychosocial and environmental predictors with biological measures studied by research scientists.<sup>17,19</sup> The movement to a more comprehensive approach stems partly from the recent shift in thinking about population health, in which academic and governmental reports have proposed increasingly complex conceptualizations of health determinants. These frameworks generally classify determinants of disease into 5 broad domains: genetics and biology, social environment, physical environment, health-influencing behaviors, and medical care.<sup>6,8,9,12,14,20</sup> Drawing on these theories, key concepts in the development of a theory for oral health include multiple levels; interactions across

levels, time, and space; equilibria and feedback loops; and the concept of vulnerability and resilience.\*

As evidence has accumulated showing that social, economic, and environmental factors also contribute to oral health outcomes,<sup>21</sup> dental epidemiologists have taken greater interest in population-based models of children's oral health. Much of the path-setting work focused on early childhood caries,<sup>22-24</sup> whereas others have looked at the interaction of oral health and socioeconomic factors over time, using a life-course approach.<sup>25</sup> These studies proceed from the basic biological model and incorporate additional influential factors in the social and physical environment of children, including socioeconomic status, ethnicity, culture, stress, health behaviors, and the health care system.

Critical to the multidimensional approach presented here is understanding that influences do not act in isolation but rather via complex interactions.<sup>26,27</sup> The relative importance of these factors and operational pathways in which they function may also change with age and developmental trajectory.<sup>28</sup> This is most obvious with different dietary factors influencing the condition of primary and permanent teeth (eg, the role of bottle feeding containing sweet liquids in early childhood or of consumption of high sugar-content snacks in later childhood).

Other research laid the groundwork for more broadly conceptualizing influences on oral health (looking both inside and outside the mouth). Reisine<sup>29</sup> applied Andersen's health services utilization model<sup>30</sup> to adults' use of dental services; although she found only 1 predisposing factor (gender) and no enabling factors impacted use, she cited methodologic limitations that may have affected her analysis. Reisine and Litt<sup>31</sup> then found that including social and psychological variables improved prediction over solely biological variables. In related work, they also detailed how dental knowledge and life stress contribute as predictors of decayed, missing, or filled surfaces on primary teeth.<sup>†24</sup> Newton and Bower noted the void in a theoretical framework of the causal pathways among social structure, social life, and oral health and disease.<sup>21</sup> Several articles discuss incorporating psychosocial and behavioral indicators for dental health conceptually, but few have tested these empirically.<sup>18,23,32,33</sup> A more intricate understanding of the context in which dental health occurs could better predict outcomes.

Recent work in population health emphasizes the multilevel nature of health determinants. Factors influencing health are expressed at the individual, family, and community levels<sup>7,34-37</sup>; indeed, simple models, indi-

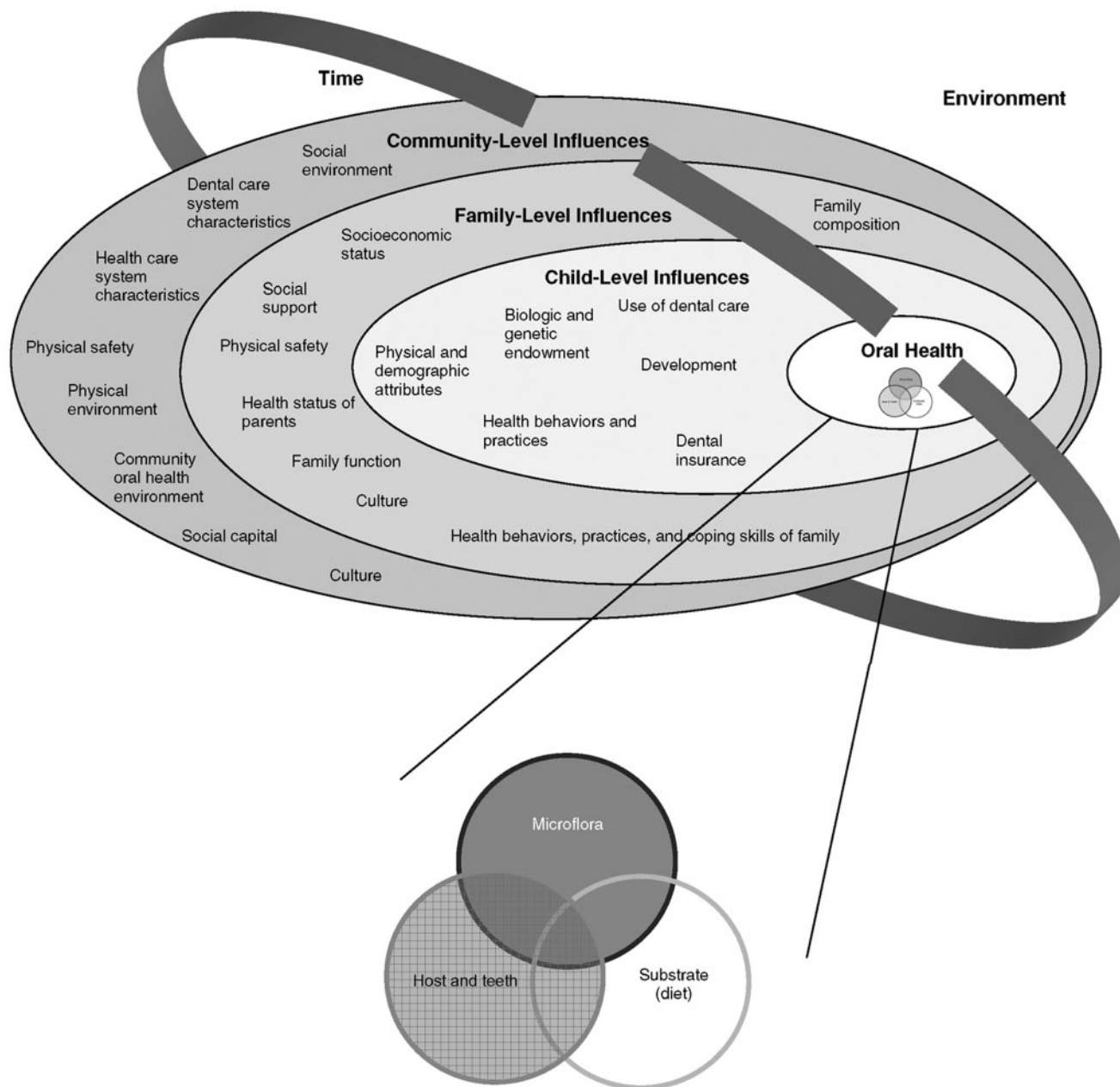
\*This last point serves as the basis for all interactions. Specifically, psychobiological and medical research shows that some individuals possess characteristics enabling successful adaptation to adversity. This can happen on a biological (host resistance to microbiologic attack) or population (individual ability to overcome adverse housing, socioeconomic, or violent environments) level, which can protect against or predispose to poor outcomes.

†In this article, as in the literature, DMFT refers to permanent teeth. Although DEFS (decayed, extracted, or filled surfaces) in primary or permanent teeth are more precise measures, the abbreviations are used as by the referenced authors. Usually the reason for an extracted or missing tooth in these indices is because of dental caries and not other reasons such as injury, orthodontic extraction, or periodontal disease.

vidually based, are no longer adequate. Individual children live in families; families are embedded in communities. In this mobile age, both people and disease vectors travel between communities. Studies have shown that general health is correlated with oral health (particularly with self-reported health status).<sup>38</sup> Because the mouth is part of the body, a child's risk of oral disease cannot be separated from his risk of overall illness.<sup>2,39,40</sup> Likewise, a child's risk of general illness and dental disease in particular cannot be isolated from family and community disease risk. Hence, any realistic model of children's oral

health outcomes must incorporate a multilevel perspective (as some oral health researchers are starting to do<sup>41,42</sup>).

Our conceptual model is summarized in Fig 1 and then detailed thereafter. This model builds on the previous work cited above and, importantly, incorporates influences in each of the 5 major domains identified by past research. In addition, it presents a multilevel conception of how these factors influence outcomes.<sup>7,34,35,41,42</sup> Of note, some relationships described here involve factors known to affect physical health in



**FIGURE 1** Child, family, and community influences on oral health outcomes of children. The triad was adapted from Keyes PH. *Int Dent J*. 1962;12:443–464; and the concentric oval design was adapted from the National Committee on Vital and Health Statistics. *Shaping a Health Statistics Vision for the 21st Century*. Washington, DC: Department of Health and Human Services Data Council, Centers for Disease Control and Prevention, National Center for Health Statistics; 2002:viii.

**TABLE 1** Domains of Determinants of Oral Health According to Level of Influence

Level	Genetics and Biology	Social Environment	Physical Environment	Health-Influencing Behaviors	Medical and Dental Care
Child level	Physical attributes; biological and genetic endowment; microflora; host and teeth	Substrate/diet; microflora	Health behaviors and practices (including injury-protection gear)	Health behaviors and practices; development; diet	Use of dental care; dental insurance
Family level	Health status of parents	Socioeconomic status; social support; family function; culture; health behaviors, practices, and coping skills of family	Socioeconomic status; family function; physical safety	Status of parents; family composition; family function; culture; health behaviors, practices, and coping skills of family	Health behaviors, practices, and coping skills of family
Community level	—	Social environment; social capital; culture; community oral health environment	Social capital; physical safety; physical environment (including fluoridation)	Culture	Health care system characteristics; dental care system characteristics

— indicates not applicable.

general but of which impact on oral health has yet to be studied separately. Sufficient concurrences exist between factors affecting health in general and oral health in particular, so including them in a conceptual model is reasonable, even if specific effects on oral health have not yet been identified. A time element is included, recognizing that children's oral health is dynamic; each child has a unique developmental trajectory. Lastly, implicit in the model is the concept of vulnerability and resilience. Specifically, psychobiological and medical research shows that some people possess characteristics enabling successful adaptation to adversity. This can happen on a biological (host resistance to microbiologic attack) or population (individual ability to overcome adverse housing, socioeconomic, or violent environments) level, which can protect against or predispose to poor outcomes.

Table 1 follows Fig 1, detailing the various factors affecting oral health according to the level of influence on which the factor acts and the 5 main domains as identified by past research. Because some factors fall into multiple domains, and not all domains are featured at each level, the following text does not use domain headings.

### Child-Level Influences on Children's Oral Health

#### *Biological and Genetic Endowment*

Basic human biology and organic makeup are fundamental health determinants. Genetic endowment provides an inherited predisposition to many individual responses affecting health status<sup>14,44</sup> and to particular diseases, including oral health problems. Caries is associated with reduced salivary flow (eg, from some medi-

cations), high salivary levels of cariogenic bacteria, developmental defects and susceptible dental morphology (deep pits and fissures), and special health care needs.<sup>2,19</sup> Previous caries is a risk factor for future caries<sup>45,46</sup>; the strongest predictor of decayed, missing, or filled permanent teeth (DMFT) is previous decayed, missing, or filled primary teeth/DMFT,<sup>24,47</sup> which, in turn, is influenced by the presence of bacteria or other factors causing a shift in the tooth-surface biofilm.<sup>16</sup> Lesion location can predict future caries progression and decay susceptibility.<sup>48-50</sup>

#### *Physical and Demographic Attributes*

Race and ethnicity seem to influence children's oral health both directly and indirectly<sup>51-55</sup>; mixed results on the impact of race/ethnicity appear to stem from socioeconomic and demographic confounding. Height and weight expand our understanding of children's oral health, both individually and combined: shorter height<sup>56</sup> (as a proxy for inadequate nutrition) and lower birth weight<sup>57</sup> are both associated with higher DMFT risk; increased BMI in some studies has been linked with increased periodontitis.<sup>58</sup> The relationship between BMI and caries requires additional study.<sup>59-61</sup> Gender is associated with other factors and directly impacts the timing of the mixed dentition stage,<sup>62</sup> with implications for timing of dental sealant programs.

#### *Health Behaviors and Practices*

Evidence is mounting on the connection of exercise, diet/nutrition,<sup>‡</sup> and good oral health habits to improved

‡Diet and nutrition can have independent effects, the first in terms of how food is consumed and the latter in terms of the nutritive value.

health outcomes.<sup>2,22–24,63–65</sup> Other protective factors include child self-esteem,<sup>66</sup> self-efficacy,<sup>24</sup> primary care visits<sup>52</sup> (a proxy measure for overall health-seeking behavior<sup>38,67</sup>), and protective gear use (eg, mouth guards). Going to sleep with a bottle containing a sweet liquid, bottle use duration, insufficient tooth brushing, and frequent carbohydrate consumption are risk factors for early childhood caries.<sup>22–24,63</sup> Likewise, for adolescent practices, smokeless tobacco use is associated with poorer oral health, specifically increased leukoplakia.<sup>68</sup>

### *Development*

Early childhood experiences affect subsequent well-being, coping skills, and competence, and, in turn, influence health outcomes.<sup>13</sup> A critical step is initial feeding practices, specifically breastfeeding frequency and duration, which affect development and health, as well as diet.<sup>23,69</sup> School performance is positively associated with good children's oral health<sup>70,71</sup>; poor children's oral health leads to millions of missed school days each year.<sup>72,73</sup>

### *Use of Dental Care*

Receipt of dental health services, particularly those designed to maintain and promote dental health (eg, fluorides and sealants), is associated with good oral health.<sup>24,74,75</sup>

### *Dental Insurance*

Insurance is critical to reduce financial barriers to obtain dental care for children<sup>75–77</sup>; its lack has been linked to higher probability of caries.<sup>19</sup> Insurance can have a mediating effect on other sociodemographic variables and access to care.<sup>19,52,75,77,78</sup> Still, the mere presence of insurance does not assure access to care, because the insurance may not be accepted.

## **Family-Level Influences on Children's Oral Health**

Families provide support and role modeling to children, influencing children's oral health both directly and indirectly.

### *Family Composition*

A single-parent or reconstituted household holds increased risk for childhood caries.<sup>19</sup>

### *Family Function*

Interest in the child's activities and religion (through faith-based interventions and dietary rules) can impact health.<sup>79–81</sup> Effective responses to stress and the support of family and friends seem to act as buffers against health problems. Whether a family experiences frequent residential moves or has immigrated also affects children's oral health.<sup>47,52,82</sup>

### *Socioeconomic Status*

Parents' education and income impact their children's oral health status.<sup>55,56,83,84</sup> Income works both at the family and community levels in influencing health, both directly and indirectly. Higher income promotes improved living conditions, such as safe housing and ability to buy sufficient, healthy food. There is evidence of powerful biochemical and physiologic links between the individual socioeconomic experience for economically disadvantaged children and adverse health events.<sup>26</sup> Children born in low-income families are more likely to have low birth weights<sup>11,85</sup> (which impacts oral health as described above). They also have more difficulty in school; poor oral health can increase school absence, further exacerbating school performance problems.<sup>52</sup> Socioeconomic status can further influence health literacy, which, in turn, affects health.

### *Health Status of Parents*

Parents' health status and stress levels influence their trust in and use of health care services, for both themselves and their children.<sup>12,24,31,52,86</sup>

### *Health Behaviors, Practices, and Coping Skills of Family*

Key health influences are family environments that enable and support healthy choices and lifestyles (eg, modeling of good oral health by siblings or mothers),<sup>87</sup> parental coping skills, and self-efficacy for dealing with life in healthy ways.<sup>13,24,31,88–90</sup> Satisfaction with care and trust in the dental system reinforce the value of oral health.<sup>52,91</sup> Periconceptual consumption of folic acid can help prevent cleft lip and palate.<sup>92</sup> Some parental characteristics can have either positive or negative effects on oral health, such as health beliefs<sup>23</sup> and birth order<sup>57</sup> (eg, parenting skills improve with later children but with more demands on parents' time). Negative parental influences include prechewing food, sharing utensils/spoon feeding, or sucking pacifiers "clean" (high cariogenic bacteria levels in saliva can be transmitted)<sup>87,93</sup>; perceiving high costs of care<sup>94,95</sup>; or having external locus of control,<sup>31</sup> fear of pain with dental treatment or general dental anxiety,<sup>22,23,96</sup> or substance abuse (significantly related to orofacial injuries<sup>97</sup>).

### *Social Support*

Support from families, friends, and communities is associated with better health. Children's greatest social support initially comes from their family; this support transitions to being largely from peers. In general, social isolation is associated with engaging more in risk-taking behaviors and less in health-promoting activities,<sup>14,26,98,99</sup> which, in turn, could endanger oral health (eg, greater use of tobacco and alcohol as a risk factor for periodontal disease and oral cancer).

### *Culture*

Culture has a myriad of influences, at the family level (eg, on language, diet, health care use, and family interactions) and at the greater community level (discussed below). Primary language spoken at home indicates degree of acculturation, which can affect oral health in different ways. Some groups have better oral health outcomes with lengthier periods of acculturation: for example, Haitian immigrants in New York<sup>100</sup> and Vietnamese in Australia.<sup>101</sup> More acculturated Mexican Americans, Cuban Americans, and Puerto Ricans in America use increased dental care,<sup>102</sup> although studies have shown differences in the impact of acculturation on different immigrant minorities.<sup>103</sup>

### *Physical Safety*

Abuse or trauma can cause dental<sup>97,104</sup> and orofacial injury.<sup>57,105</sup>

### **Community-Level Influences on Children's Oral Health**

Health care research increasingly examines influences beyond the individual to explain health. For a child, these contextual variables include home, neighborhood, community, and state characteristics.

### *Social Environment*

Neighborhood stability, safety, cohesion, and educational attainment provide a supportive social environment that can ameliorate potential risks to good health. Dental morbidity has been linked with high neighborhood poverty rate.<sup>51</sup> Moreover, income inequality in a community inversely affects general health<sup>85,106</sup> and children's oral health.<sup>107</sup> The healthiest populations are in prosperous communities and societies with the least income inequality.<sup>9,106-109</sup>

### *Social Capital*

Borrowed from sociology and economic research,<sup>110,111</sup> social capital (the networks and social relationships that facilitate interaction and access to information and resources) has health implications that are well summarized by Ziersch.<sup>112</sup> Much research discusses how social capital influences overall health,<sup>85,113,114</sup> but little focuses on oral health, with the notable exceptions of Watt<sup>115</sup> and Pattussi et al.<sup>116,117</sup>

### *Physical Safety*

Trauma, either from unsafe playgrounds or more overt violence, can cause dental<sup>97,104</sup> and orofacial injury.<sup>57,105</sup>

### *Physical Environment*

Public health measures, such as optimal fluoridation of public water supplies, reduce dental disease.<sup>19,118</sup> As has been seen in research in population health, factors in the human-built environment, such as population density/urbanicity, housing quality, community attributes (in-

cluding availability of grocery shopping and healthy food options), transportation resources, and crime also are important influences.<sup>6,11,119</sup>

### *Community Oral Health Environment*

Positive community-level initiatives, such as oral health promotion campaigns (including school- or community-based sealant programs) and public policy, are associated with improved children's oral health. Children's oral health is likely to be better when they live in a community that values good oral health.<sup>115,120</sup>

### *Dental Care System Characteristics*

The type and amount of dental care available vary by neighborhood and state. There is diversity in the type and number of practitioners, percentage who participate in Medicaid and other government dental programs, number willing to treat children, state licensing practices and scope of practice rules, and percentage of residents with dental insurance.<sup>121,122</sup>

### *Health Care System Characteristics*

Outcomes are known to vary by geography and insurance status and coverage. An effective health care system has available preventive care, a low proportion of beneficiaries in a medically underserved area, and a low infant mortality rate. Children receiving referrals to a dentist from a pediatrician are more likely to be taken to the dentist<sup>123</sup> and at a younger age.<sup>94</sup>

### *Culture*

Culture, through cultural norms and practices, influences a wide range of factors affecting children's oral health, such as belief systems, behaviors, and practices (especially diet). Culture affects preventive orientation, care-seeking behavior, and dental fear. A community's culture influences its values, beliefs, and customs, which affect views on oral health and oral health service use. Culture is reflected in religion and religious practices, health beliefs, social norms, language, diet, family structure and social function, preventive oral health service use, and attention to dental hygiene (see also discussion of culture under "Family-Level Influences on Children's Oral Health"). Specifically, culture has been found to affect tooth-brushing habits and methods, diet, perceived seriousness of tooth decay, and individual control over tooth decay.<sup>124,125</sup> Caries rates have been found to vary by ethnicity.<sup>31,126-129</sup> Racial/ethnic differences are even seen in the way adolescents are impacted differently by parenting style and peer support.<sup>130</sup>

### **Time Influences on Children's Oral Health**

The model in Fig 1 incorporates not only the many types and levels of influences on children's oral health but also accounts for changes over time. Recognizing that health and its determinants form a dynamic, evolving system,

the model includes time.¶ Thus, this model guides consideration of appropriate places and times in the child's, family's, and community's developmental trajectory to direct interventions.

### EMPIRICAL APPLICATIONS OF THE CONCEPTUAL MODEL

This conceptual model of oral health is based on a solid foundation of social science and epidemiologic studies of population health. As applied to children's oral health, it appropriately includes multiple levels of influences, including a time or developmental dimension. The particular factors chosen are based on a wealth of research identifying key influences on children's oral health, including genetic and biological, social and physical environment, support system, health behaviors, and dental and medical care.

These very strengths of our conceptual model create a number of challenges in its empirical application. The first challenge is finding sufficiently large data sets with the necessary independent and dependent variables to provide enough power to study multiple factors concurrently. A truly complete database would include a longitudinal component to adequately measure the time factor and data collected at various levels (individual, family, and community). The next challenge, assuming appropriate data sets are available, relates to selecting variables within each domain. Paring down the potentially very large set of variables in our conceptual model to a parsimonious and measurable subset could eliminate potentially important factors if not done carefully.

One of the most challenging issues in developing realistic conceptual and empirical models is causality, given the complex interplay of the factors involved. Causal relationships can be expressed directly and indirectly and can exhibit reciprocal causal forces or feedback loops. For instance, a change in the social environment can influence social support systems. Through a feedback loop or reciprocal causal path, those changes in social support systems can effect the social environment. In addition, causal forces may be mediated by other factors, such as a child's natural or acquired resistance or resilience to disease; this multifaceted nature has led some authors to liken population health to a "web of causation."<sup>131,132</sup> The challenge, of course, is in developing conceptual and empirical models that are realistic. Simple models that propose a direct cause-and-effect relationship between a single risk factor and an outcome are more amenable to empirical modeling but may fail to adequately account for confounding and interactions among variables. Consequently, such models may be of limited predictive use or low external validity. Other models can be so complex that they cannot be empirically estimated or even understood in the 2 or 3 dimen-

¶The time element in our model is meant to account not only for the direct effect of the passage of time but also for the indirect effects of changes over time in the other factors incorporated in the model.

sions normally used to conceptualize relationships. The model presented here takes a middle path, one that is comprehensible yet sophisticated enough to add value. Even so, it is important to recognize that reciprocal causal relationships exist among the variables included in the model. Although structural equation models can model mediating effects, their application requires additional assumptions and adds complexity in interpretation.

Another concern relates to specifying the functional form of the causal relationships; whereas most commonly used statistical modeling techniques assume linear relationships, few natural processes are purely linear. Other challenges relate to the multiple levels of influence in our conceptual model. Multilevel modeling is now an accepted analytic strategy, but specifying the appropriate levels of analysis in multilevel modeling is not always straightforward; for example, should census tracts, zip codes, counties, states, or some other geographic units be used?

Finally, this is a general model of the factors influencing children's oral health outcomes. One can recognize that this is, in fact, a great simplification, because oral health status is composed of many dimensions, including appearance, functionality, current and past disease, receiving treatment, and having pain/infection. The relative importance of genetic endowment, the physical and social environment, health behaviors, and the health care system will likely vary across the particular oral health outcome measure used in an empirical model.

### CONCLUSIONS

Traditionally, children's oral health research has focused on a handful of biological and environmental factors, with poor predictive results. Water fluoridation was the focus of this research, which contributed to an increase in fluoridation prevalence and a decrease in caries prevalence. Still, more than half of children ages 5 to 9 years old have or have had caries; a greater burden of oral health disease is borne by children of disadvantaged socioeconomic status or race/ethnicity other than the majority group.<sup>2</sup> New analytical approaches are needed to guide the next stage of public health policy to combat still high levels of dental caries.

Recent progress in applying new multivariate statistical methodologies in overall public health suggests that applying an appropriately complex, yet manageable, model to children's oral health also will result in improvements in predictive power. The conceptual model draws on the established public health literature to guide the selection of levels, relying on recent oral health research to hone in on the key variables within each level (child, family, and community). No study or other iterations of this model has yet included such an extensive list of factors.

A conceptual model shows its greatest value when it

can be used empirically. This model will be applied to a database that evaluates these influences, recognizing that simplifying our conceptual model will be necessary. Much as this model has looked to other areas of public health research for guidance, applying suitable multivariate methodologies to children's oral health prevention is likely to contribute to the development of improved models in other areas of public health.

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## Influences on Children's Oral Health: A Conceptual Model

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