Estimating Prevalence and Severity of Caries in the Mixed Dentition: a Comparison of Two Screening Protocols

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Abstract

Objective: *Most oral health surveys examine and record data on individual teeth or surfaces (STD), providing valid estimates of caries prevalence and severity. Simplified screening protocols based on assessments at the person level (Stop-After-First-Encounter—SAFE) have been validated for assessment of prevalence. We developed an alternative protocol (SENTINEL), which examined the 12 teeth at highest risk for caries and compared how it performed to SAFE and STD for surveillance and evaluation.* ***Methods:*** *We used data from the Third National Health Nutrition and Examination Survey for children aged 8 to 12 years to analyze the feasibility of assigning STD estimates of severity to children designated by SAFE as having caries. SENTINEL was tested for accuracy of estimating prevalence and severity against STD. In addition, we used subsampling to test the frequency with which SAFE and SENTINEL agreed with STD in identifying the highest risk population. Finally, we compared the mean number of teeth and the recorded data elements for each protocol.* ***Results:*** *Assigning national estimates of severity to SAFE provided inaccurate estimates. SENTINEL agreed with STD in identifying the survey group with the highest severity more frequently than did SAFE (96 percent vs 74 percent). SAFE on average examined nine more teeth than SENTINEL.* ***Conclusions:*** *Both SAFE and SENTINEL could serve as surveillance tools, depending on the system's purpose/objectives. However, it is unlikely that SAFE would provide adequate information to evaluate sealant programs. [J Public Health Dent 2004;2004;64(1):14-19]*

Key Words: screenings, surveys, surveillance, dental caries, pit and fissure sealants.

Public health surveillance is the ongoing systematic collection, analysis, and interpretation of outcome-specific data for use in planning, implementing, and evaluating public health practices (1,2). In oral disease surveillance, one source of data has been intraoral assessment at the national, state, and local level. At the national level, the most current data come from the Third National Health Nutrition and Examination Survey (NHANES III) (3). Protocols for dental caries used in these surveys collect data for all teeth and dental surfaces (STD) and are considered to provide unbiased, valid, and reliable estimates of disease prevalence and severity.

Because these protocols are extremely resource-intensive, few states have used them to collect data on an ongoing basis (4). To simplify caries data collection, the Division of Oral Health at the Centers for Disease Control and Prevention developed and validated a simplified visual-only protocol that determined, among other indicators, the prevalence of caries experience, untreated decay, and dental sealants (5). The Association of State and Territorial Dental Directors later adopted this protocol, calling it the Basic Screening Survey (6). Although the protocol does not specify the sequence in which participant's teeth should be examined, the dental examiner frequently begins with the upper right second molar, then continues assessing subsequent teeth, stopping only after finding a tooth with the outcome of interest, e.g., a tooth with untreated decay. We will refer to this procedure as "Stop After First Encounter," or SAFE. If the first examined tooth (i.e., second molar) has untreated decay, the examiner stops and records that the person has both untreated decay and caries experience. Conversely, if a person has no untreated decay the examiner must examine all erupted teeth. Thus, SAFE is intended to provide valid estimates of caries prevalence, but does not provide information on severity.

More detailed data (i.e., tooth or surface level) may be needed to assess the effectiveness of caries prevention programs (7-9). For example, estimating averted disease attributable to a sealant program will require data on pit and fissure surfaces for specific teeth (10).

Our research had three objectives. First, we examined if caries prevalence data from SAFE could be combined with data from national surveys to estimate severity. If children with disease all had similar levels of severity, then we could assign estimates of severity obtained from national surveys to children designated by SAFE as having caries. Second, we examined the accuracy and precision of prevalence and severity estimates obtained from an alternative screening protocol (called SENTINEL) developed for this study. SENTINEL visually assesses a subset of the dentition, which includes the teeth at highest risk for developing caries. Finally, we examined how "efficient" SENTINEL and SAFE were in allocating prevention resources (i.e., when selecting between two communities with different numbers of carious teeth, how frequently would each

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protocol select the community with the highest value) and in saving screening resources (i.e., number of teeth screened and data elements recorded).

Methods

We restricted our analysis to children aged 8 to 12 years because caries prevention programs typically target children in these age groups. Also, we conducted separate analyses for children from low-income families (family income ≤200 percent of the federal poverty level) because dental caries prevention interventions may target lower income populations. In our analysis, we assumed that the type of screening protocol was the only source of bias (no measurement error by the examiner).

We used dental data from NHANES III, conducted in 1988–94, for 2,593 children representing 18,353,361 children nationwide. NHANES III used a visual-tactile protocol (3), which examines each tooth surface using a dental mirror and explorer. Additional information on sampling methodology and diagnostic criteria on this survey can be obtained from Drury et al. (11).

We estimated the prevalence and severity of three caries indicators: (1) caries experience (prevalence: dft+DMFT>0; severity: mean dft+DMFT); (2) untreated decay (prevalence: dt+DT>0; severity: mean dt+DT); and (3) permanent first molar caries (prevalence: $DMFT_{1molars}>0$; severity: mean $DMFT_{1molars}$) that would be obtained from each screening protocol. These indicators were selected for their utility in monitoring both burden of disease (caries experience and untreated decay) and effectiveness of school-based sealant programs (permanent first molar caries). We used values obtained from STD as the true population parameters, the "gold standard."

Extrapolating Estimates of Caries Severity from SAFE. To examine the feasibility of combining prevalence data obtained from SAFE with mean severity values among affected children obtained from NHANES III we examined the distribution of the absolute deviation (AbDev) of these estimates from the true value.

$$AbDev = | Indicator_{STDi} - Indicator_{EXTSAFEj} | \qquad [1]$$

where:

$Indicator_{STDi}$ = true severity value of indicator for the i^{th} child (i.e., STD)

$Indicator_{EXTSAFEj=1}$ = mean value of indicator (obtained from STD) among children designated by SAFE as having condition

$Indicator_{EXTSAFEj=0} = 0$ among children designated by SAFE as not having condition

Estimating Severity and Prevalence with SENTINEL. To determine teeth to be included in SENTINEL, homologous (contralateral) teeth were ranked separately for each jaw. Starting with the tooth pair with the highest probability of experiencing caries, we added the tooth pair with the next highest probability, and so on. We examined the shape of the cumulative frequency distribution (Figure 1) to determine whether a natural cut-off point existed. First permanent molars, second primary molars (second premolars), and first primary molars (first premolars) captured 94 percent of teeth with caries experience. Thereafter, we calculated values for the three indicators using these 12 teeth.

To determine how well SENTINEL would estimate prevalence of the three indicators of caries, we compared estimates obtained from SENTINEL to the true prevalence (i.e., STD). To determine how well SENTINEL would measure severity of each indicator, we again examined the frequency of the absolute deviation of SENTINEL estimates from the true value.

$$AbDev = | Indicator_{STDi} - Indicator_{SENTINELi} | \qquad [2]$$

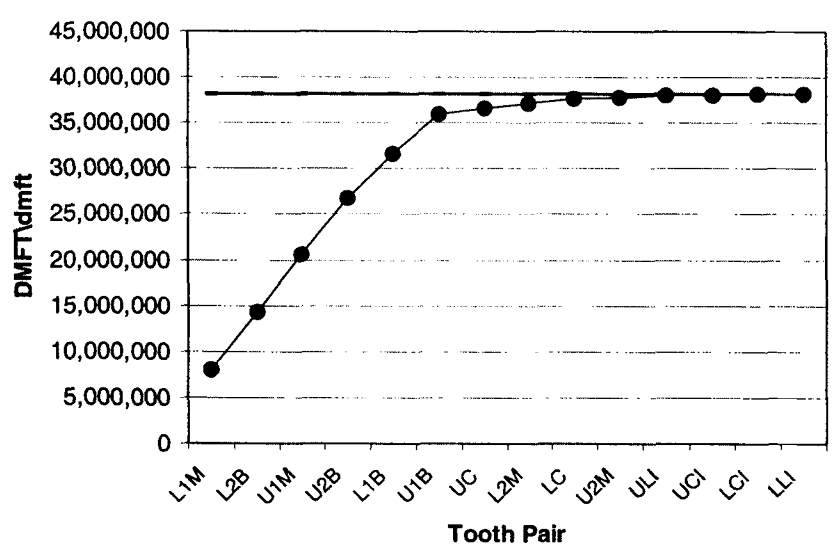
where:

$Indicator_{STDi}$ = true value of indicator of severity (i.e., STD) for the i^{th} child

$Indicator_{SENTINELi}$ = value of indicator of severity for the i^{th} child

To examine how frequently SAFE and SENTINEL would agree with STD in selecting the population with the highest severity, we created two data sets from NHANES III: one set with all children aged 8 to 12 years, regardless

FIGURE 1
Cumulative Frequency of Decayed, Missing* (Due to Caries), and Filled Teeth (Both Dentitions) Adding Additional Pairs of Teeth†‡ with the Next Highest Probability of Being Affected by Caries, United States, Children Aged 8-12 Years, National Health Nutrition and Examination Survey III (1988–94)



*Only in permanent teeth.
†M represents molar, B represents bicuspid, C represents canine, LI represents lateral incisor, CI represents central incisor.
‡Second bicuspid (2B) may be primary second molar and first bicuspid (1B) may be primary first molar. "L" designates tooth pair in lower arch and "U" designates tooth pair in upper arch. For example, L1M designates permanent first molars in lower arch.

of family income, and a second set including only children from low-income families. We next expanded each data set such that each would have approximately 2,000,000 observations. We replicated each child's weight by a factor of 1/9 in the data set including all families regardless of income (This is equivalent to dividing the weighted sample size by 9; $^{18,353,361}/_{9} \cong 2{,}000{,}000$) and 1/4 in the set including low-income families. Then, for each data set we used the SAS procedure RANUNI to randomly assign each observation to one of 2,000 subsamples. Thus, each subsample had approximately 1,020 observations for all families and approximately 1,059 for low-income families.

For each subsample we calculated the severity of caries experience obtained from the STD protocol and from the SENTINEL protocol, as well as the prevalence of caries experience obtained from the SAFE protocol. We then conducted 1,000 trials (each trial included a set of two subsamples) in which we determined if SENTINEL and SAFE agreed with STD in selecting the subpopulation with the highest severity of caries experience. For example, if severity (calculated with STD) were highest in the first subsample, then SENTINEL and SAFE would agree with STD if severity calculated with SENTINEL and prevalence were also highest for the first subsample. We used the same process to evaluate how well SENTINEL and SAFE would target resources if the criteria were untreated decay and permanent first molar caries. We also calculated the kappa coefficient to determine if differences in agreement of the two protocols with STD were systematic or

TABLE 1
Estimates of Prevalence for Three Caries Status Indicators, United States, Children Aged 8–12 Years, National Health Nutrition and Examination Survey III (1988–94)

	Children % (All Families) (weighted n=18,353,361)		Children % (Restricted to Low-income Families*) (weighted n=8,468,856)	
Indicator	STD	SENTINEL	STD	SENTINEL
Caries experience	58.36	57.36	64.54	63.80
Untreated decay	25.78	23.85	34.67	31.81
Permanaent 1st molar caries†	34.22	34.22	37.58	37.58

*Household income less than 200% of the federal poverty level.
†99.5 percent of children with carious permanent first molars experienced caries in the pit and fissure surfaces.

TABLE 2
Frequency of Absolute Deviation about True Value of Severity Indicator, United States, Children Aged 8–12 Years, National Health

	% Children from All Families (Weighted n=18,353,361)*				% Children from Low-income Families (Weighted n=8,468,856)*†			
Mean Absolute Value from	Assigning NHANES III Estimates to SAFE		SENTINEL		Assigning NHANES III Estimates to SAFE		SENTINEL	
True Deviation	dft+DMFT	dt+DT	dft+DMFT	dt+DT	dmft+DMFT	dt+DT	dft+DMFT	dt+DT
0	41.64	74.22	91.35	94.46	35.46	65.33	88.25	91.67
(0,1]‡	15.54	8.09	6.05	4.04	20.11	11.78	8.61	6.31
(1,2]	17.92	15.10	2.02	1.19	15.96	18.60	1.92	1.36
(2,3]	17.48	1.14	0.28	0.20	17.27	2.24	0.56	0.41
(3,4]	2.64	0.79	0.27	0.11	3.24	1.20	0.56	0.25
(4,5]	2.54	0.19	0.04	0.00	3.37	0.38	0.09	0.00
(5,6]	0.89	0.21	0.00	0.00	1.07	0.21	0.00	0.00
(6,7]	0.73	0.08	0.00	0.00	0.55	0.17	0.00	0.00
(7,8]	0.46	0.14	0.00	0.00	0.93	0.01	0.00	0.00
(8,9]	0.10	0.00	0.00	0.00	0.21	0.00	0.00	0.00
(9,10]	0.01	0.04	0.00	0.00	0.01	0.09	0.00	0.00
(10,11]	0.01	0.00	0.00	0.00	0.09	0.00	0.00	0.00
(11,12]	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00

*For children from all families, NHANES III estimate of severity among affected children equaled 3.56 for caries experience, 2.18 for untreated decay, and 1.33 for first molar caries among children with caries experience. For children from low-income families, these values, respectively, equaled 3.70, 2.29, and 1.36.
†Household income less than 200% of the federal poverty level.
‡(a,b] represents interval including all values greater than a and less than or equal to b.

TABLE 3
Proportion of Trials in Which Protocol Agreed with STD in Targeting Resources Based on Caries Indicators (1,000 Trials) and Average Number of Teeth Missed per Trial, United States, Children Aged 8–12 Years, National Health Nutrition and Examination Survey III (1988–94)

		SENTINEL		SAFE	
Caries Severity Indicator	Family Income	% Trials in Agreement (Total)	Average # Teeth Missed per Child	% Trials in Agreement	Average # of Teeth Missed per Trial
Caries experience	All* (kappa=3%)	95.7	0.004	73.5	0.042
	Low†‡ (kappa= 15%)	94.2	0.006	71.6	0.051
Untreated decay	All* (kappa=14%)	90.6	0.001	76.3	0.006
	Low†‡ (kappa= 17%)	90.4	0.001	75.7	0.007
Permanent first molar caries	All*	100	0.00	64.0	0.011
	Low†‡	100	0.00	67.3	0.011

*Average number of observations per sample for each protocol equaled 1,020.
†Average number of observations per sample for each protocol equaled 1,059.
‡Household income less than 200 percent of the federal poverty level.

due to random error.

To estimate the mean number of teeth to be examined with SAFE, we divided the children into two groups: (1) those with an erupted upper right second molar and (2) those without an erupted upper right second molar. We assumed that the latter group had no erupted second permanent molars (i.e., 24 erupted teeth). For each group, we calculated the probability that the first tooth examined (i.e., the upper right second molar or upper right first molar) had untreated decay, then the probability that the next examined tooth had untreated decay given the previous examined tooth had no untreated decay, and so on, until we reached the last tooth to be examined (i.e., lower right second molar or first molar). Then, we multiplied the probability that the first tooth examined had untreated decay by 1, the probability that the second tooth had untreated decay conditioned upon the first being sound times 2, and so on. Furthermore, we added to the sum of these values the product of the probability that a child had no untreated decay and 28 (erupted second molar) or 24 teeth (no erupted second molar).

Results

Approximately 58 percent of all children and 65 percent of low-income children had experienced caries (Table 1). The mean DMFT+dft equaled 2.07 and mean DT+dt equaled 0.56. Because SENTINEL examined a subset of the dentition, it always underestimated the prevalence and severity of caries experience and untreated decay; it captured approximately 98 percent (bias=–1.7 percent) of caries experience cases (mean severity=1.96 teeth) and 93 percent (bias=–7.5 percent) of untreated decay cases (mean severity=0.49 teeth). SENTINEL provided valid estimates of permanent first molar caries prevalence, because this tooth was included in the protocol. Only 58.6 percent of children who experienced caries also experienced permanent first molar caries.

All of the indicators of caries severity were positively skewed (data not shown) suggesting that severity estimates could not be extrapolated from national estimates of severity and prevalence data obtained from SAFE. Caries severity estimated by extrapolating estimates of caries deviated from the true value in over 58 percent of children (range=0–12 teeth) (Table 2). Untreated decay severity deviated from the true value in 26 percent of children (range=0–10 teeth). Absolute deviation from the true value was higher among low-income children.

SENTINEL estimates of caries severity deviated from the true value in less than 10 percent of children (range=0–5 teeth) (Table 2). The deviation of untreated decay from the true value was equal to 0 in approximately 95 percent of children (range=0–4 teeth). Again, absolute deviation from the true value was higher among low-income children.

For a hypothetical program to avert caries among children from all families, SENTINEL would allocate resources to the same groups as would STD, 96 percent of the time, whereas SAFE would do so 74 percent of the time (Table 3).

Targeting prevention based on information obtained from SAFE versus SENTINEL would have resulted in approximately 40 fewer at-risk teeth per 1,000 children receiving primary prevention. When the targeting criterion was permanent first molar caries, SENTINEL agreed with STD 100 percent of the time, whereas SAFE agreed 64 percent of the time. The kappa coefficient for measurement of agreement was less than 20 percent for caries experience and untreated decay for all income groupings, suggesting that the agreement between the two protocols with the gold standard, STD was slight (i.e., SENTINEL's higher proportion of agreement was not due to chance) (12). To examine if proportion of agreement varied by sample size, we also ran the simulations for samples with 25, 50, and 100 observations. The proportion of trials in which SAFE agreed with the gold standard ranged from 71 percent to 74 percent, while the proportion of trials in agreement for SENTINEL ranged from 95 percent to 96 percent. Limiting the analysis to children from low-income families yielded similar results (Table 3).

Following the SENTINEL protocol,

dental examiners examined and recorded data for 12 teeth, whereas the number of teeth examined using SAFE varied based on severity. In our research, among the 77 percent of children with an unerupted permanent second molar, the mean number of teeth examined under SAFE was 19.98; among the 23 percent of children with an erupted permanent second molar, the mean number of teeth examined was 24.47. Thus, the average number of teeth examined under SAFE was 21.

Discussion

Experts have stated that "planning a surveillance system begins with a clear understanding of the purpose of surveillance, i.e., the answer to the question what do you want to know?" (1). In other words, establishing objectives for surveillance must occur early in the planning process; these objectives serve as the foundation for making decisions regarding appropriate surveillance measures and methods.

Oral health surveillance data on prevalence, for which SAFE is a valid protocol, have been used at both the state and national level to monitor progress in attaining national and state health objectives (e.g., Healthy People 2010 national objectives). SAFE information has also been used to track the nation's performance over time and to benchmark individual state performance (13). In addition, information acquired through SAFE can be used to identify people in need of dental referral (14,15). Thus, SAFE has been shown to provide reliable data for the purpose of surveillance.

Some states or programs may seek data on severity to target preventive resources toward the highest-risk populations or to evaluate a program's impact on the burden of disease. By obtaining caries surveillance data that estimates both the prevalence and severity of caries, decision makers can more precisely target primary and secondary prevention, potentially maximizing the amount of disease averted per prevention dollar. These surveillance data can also be used to estimate both the clinical and financial effects of various approaches, thereby quantifying the return on investment in community interventions. At the state and local level, effectiveness and cost-effectiveness data, which require estimates of disease averted, may prove advantageous to programs attempting to obtain and retain scarce resources. Ideally, one might chose unbiased, detailed data on both prevalence and severity as provided by STD. The value of that additional information obtained using STD, however, may not justify the additional cost.

SAFE was developed to simplify the process and thereby reduce the cost, of collecting and recording surveillance data. Using the SAFE protocol to target prevention assumes that prevalence data are sufficient for efficient resource allocation. However, it is not clear that allocating prevention resources to avert *cases* will also minimize the associated costs of averted disease. If productivity losses, treatment costs, and intangible costs such as pain and suffering increase as the number of affected teeth increases the allocation of resources based on severity data may prove to be more efficient.

SAFE was not designed to provide estimates of severity and our findings suggest that it is unlikely that combining information from SAFE with that of other data sources will produce accurate severity estimates. In addition, it is unlikely that estimates of first molar caries prevalence can be extrapolated from SAFE; only 58.6 percent of children with caries in the mixed dentition also had permanent first molar caries. SENTINEL provided accurate estimates of both prevalence (agreement with true value exceeded 98 percent for caries and permanent first molar caries and 92 percent for untreated decay) and severity (agreement with true value between 88 and 91 percent for caries and 92 to 94 percent for untreated decay) for each of the three indicators of caries. In addition, our subsampling suggests that SENTINEL is more likely than SAFE to agree with STD in selecting the population with the highest severity. Assuming that allocation based on severity is more efficient than one based on prevalence, the use of SENTINEL instead of SAFE would increase the probability that caries prevention resources were targeted to the population with the highest severity by approximately 30 percent for caries, 19 percent for untreated decay, and 56 percent for permanent first molar caries. SAFE's relatively poor performance in targeting resources to prevent permanent first molar decay suggests that programs offering sealant programs may want to collect additional information on caries experience in first permanent molars.

SENTINEL also may lower data collection costs, depending on the availability of a data recorder. On average, SENTINEL examines fewer teeth, but requires more data elements to be recorded. When a recorder is present, the additional costs of recording data approach 0; that is, the screener calls the data as teeth are screened. With a recorder, recording the additional pieces of information included in SENTINEL would unlikely require additional time. The reduction in the number of teeth examined would lead to an average savings of more than 42 percent in variable time costs. Without a recorder, SENTINEL, however, would unlikely be a viable protocol.

This research had at least two limitations. First, we assumed that NHANES III data were an accurate representation of the true population. Because that protocol did not include radiographs, it likely underestimated decay. Thus, our findings on agreement of SAFE and SENTINEL with the true population are probably overstated.

In addition, we did not address the issue of examiner measurement error. For example, SENTINEL would not be a feasible protocol if an examiner could not correctly identify permanent and primary molars. Neither protocol would perform well if examiners could not correctly identify caries. For example, if we were to assume that measurement error were independent for each tooth and the probability of error were 5 percent, then SENTINEL would correctly classify 52 percent of the teeth [$0.945 * (1-.05)^{12}$]. SENTINEL, however, would have higher specificity in estimating prevalence than would SAFE; among caries-free children, SAFE must accurately diagnose all teeth as being caries free, whereas SENTINEL must only diagnose 12. For a child with 24 erupted teeth, specificity for SAFE would equal $0.95^{24}=0.29$, whereas it would equal $0.95^{12}=0.54$ for SENTINEL. SAFE, however, will always have slightly higher sensitivity. Sensitivity with SAFE would equal 1 minus the probability that all affected teeth were misdiagnosed and no sound teeth were misdiagnosed. Among children with caries experience, the mean number of affected teeth equals approximately 3.55; thus, sensitivity with SAFE would equal $1–0.05^{3.55}0.95^{20.45}>0.99999$. Sensitivity with SENTINEL would equal $1–0.946 * 0.05^{3.42}0.95^{8.58}>0.9999$. Admittedly, we are oversimplifying because it is likely that measurement error is not independent and the probability of false negatives may not equal that of false positives. But our point is that as measurement error increases, SENTINEL will provide less accurate estimates of severity. However, among populations with low levels of disease, it should provide better estimates of prevalence than will SAFE.

In conclusion, both SAFE and SENTINEL could serve as appropriate surveillance measures, depending on the purpose and objectives of the surveillance system. Our research underscores the importance of first establishing the purposes of the surveillance system before selecting the screening protocol and data collection methods.

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