

## BRIEF COMMUNICATION

# Total observed caries experience: assessing the effectiveness of community-based caries prevention

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## Keywords

dental caries, oral health, child

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Received 7/31/2017; Accepted 6/5/2018.

doi: 10.1111/jphd.12284

Journal of Public Health Dentistry **78** (2018) 287–290

## Abstract

**Objectives:** To compare common measures for dental caries in longitudinal caries research in support of a new measure, the Total Observed Caries Experience (TOCE).

**Methods:** TOCE was calculated as the total number of decayed or filled teeth ever observed. TOCE was compared to dmft, DMFT, and the prevalence of untreated decay using data from a 4-year, cluster randomized community-based caries prevention program. Outcomes were analyzed using generalized estimating equations and assessed change over time and effects across treatment groups.

**Results:** For TOCE and DMFT, the risk of caries over time increased. In contrast, risks decreased for dmft and the prevalence of untreated decay, driven largely by decayed primary teeth being exfoliated. Effects across treatment groups showed increased risk for some outcomes and attenuated risks in others; however, treatment effects for TOCE were more in line with expected results when compared with controls.

**Conclusions:** TOCE accounts for caries on primary and permanent dentition and is not subject to bias due to exfoliation. It can be used as a robust measure to evaluate community-based caries prevention programs.

## Introduction

Dental caries is the most prevalent childhood disease in the world, accounting for 3.5 million disability-adjusted life years (1,2). In an effort to reduce oral health inequity, the American Dental Association recommends community-based caries prevention programs (3). The Institute of Medicine considers the comparative effectiveness of caries prevention programs to be a top research priority (4).

To effectively evaluate the long-term impact of caries control strategies, metrics are needed that can accommodate observations that span across primary to adult dentition. Common measures used in longitudinal epidemiology studies of dental caries include the dmft/DMFT index (5), the prevalence of untreated decay, cumulative decay incidence (6), incidence density (7), and the new caries increment, typically expressed as the change in decayed, missing, or filled permanent teeth from baseline to follow-up (8). Many of these indices, however, either ignore decay on primary teeth or do not account for exfoliation, the natural process of losing primary teeth as children age. Primary tooth exfoliation leads to informative miss- ingness, which when left unaccounted for can bias treatment

effects (8–10). As the likelihood of tooth decay is dependent on the presence of the tooth, missing data due to exfoliation is nonignorable, and the exfoliation of decayed teeth should not be interpreted as an improvement in oral health. Importantly, caries prevention programs are often first given to children with mixed dentition. Thus, there remains a need for a caries outcome that includes both primary and permanent dentition and is not subject to bias due to tooth exfoliation.

To address this need, we propose the total observed caries experience (TOCE), defined as the total number of dental caries and fillings across primary and permanent dentition ever observed over time, as an alternative measure to assess community-based caries prevention. We compare TOCE with other common outcome measures for dental caries typically used in longitudinal epidemiologic caries research using data from a 4-year cluster randomized trial.

## Methods

Data were derived from a cluster-randomized trial of three caries prevention strategies given to 682 primary school-aged

children in the Philippines conducted from 2009 to 2012. Three interventions to postpone or prevent tooth decay were randomized at the school level: a) daily tooth brushing with fluoride toothpaste, b) daily tooth brushing with fluoride toothpaste plus access to urgent care for children with toothaches from advanced caries, and c) daily tooth brushing with fluoride toothpaste plus weekly application of a high-concentration fluoride gel. A fourth external control group was selected from the surrounding geographic area and received a standard health education program consisting of a physical examination and oral health messaging. The control group assignment was not randomized. Participants were observed annually for 4 years and clinically evaluated for decayed, filled, or missing teeth as well as pulpal involvement. The study was reviewed and approved by the institutional review board of the Kinaadman Research Center (Xavier University, Cagayan de Oro, Philippines) and is registered with the German Clinical Trial Register (DRKS00003431) and the World Health Organization (WHO Universal Trial Number U1111-1126-0718). This study was purposefully selected for the comparison of common indices for dental caries as the included treatments were minimally invasive and did not include interventions that would directly reduce the prevalence of existing caries (e.g., no topical fillings, silver diamine fluoride, or therapeutic restorations were provided).

Observational visits over time for each child were numbered sequentially. Any participant with missing age was excluded from analysis. To compare TOCE with common indices for dental caries, outcomes were created for TOCE, the dmft and DMFT indices, and the prevalence of untreated decay on any dentition. TOCE was calculated as the sum of the total number of teeth with either untreated decay or restoration (e.g., filling) present at each observational period, regardless of whether the affected tooth was exfoliated in subsequent observations. For example, if a child presented at baseline with a carious lesion on the mandibular molar, and at the first follow-up visit presented with a recently erupted permanent molar in the same space, the child would receive a TOCE score of one to reflect the status of the previously exfoliated decayed tooth. If the erupted permanent tooth then later develops decay or has a filling, TOCE would increase to two. Thus, the prior states of exfoliated teeth are carried over to subsequent observations, and the per-person total of decayed or restored teeth over time will either stay the same or increase. The total possible range for TOCE is 0 to 52, reflecting one possible score for each primary and permanent tooth. The actual observable range depends on the current distribution of primary and permanent teeth per child when the study begins.

Each outcome was analyzed separately using generalized estimating equations. The data structure consisted

of observations nested within children. Scores for TOCE, dmft, and DMFT were analyzed using a log link, a negative binomial family, and an exchangeable correlation matrix. For untreated decay, log link with a binomial family was used. Age was included as a continuous linear predictor and a dummy variable was included for treatment group. Models adjusted for the presence of any untreated decay at baseline (for the untreated decay outcome) or baseline TOCE scores (for count outcomes) and further adjusted for school, the number of siblings each participant had, gender, and family ownership of a television, which was included as a proxy measure for socioeconomic status and is commonly used in studies for this demographic area (11).

Results

The sample consisted of 682 children with an average age of 7 years (Table 1). The average dmft at baseline was 5.80 (SD = 4.29), average DMFT was 1.23 (SD = 1.66), and average TOCE was 4.58 (SD = 3.26). Overall, 95 percent of children had untreated decay at baseline on any tooth (primary or permanent), with 52 percent of children having decay on any permanent tooth. Approximately 66 percent of participants had a television in their household. Over the course of the study, the prevalence of children with untreated decay on permanent teeth increased from 52 percent to 91 percent.

Longitudinal model results (Table 2) show that the risk of decayed, missing, and filled primary teeth significantly decreased over time (incident rate ratios [IRR], 0.62; 95% confidence interval [CI], 0.59–0.66), as did the risk of

Table 1 Sample Descriptive Statistics at Baseline

	Overall	
	N	%
Total	682	100
Males	328	48.09
Females	354	51.91
TV in household	452	66.28
Any decay	1,728	95.00
Any decay (permanent teeth)	942	51.78
	Mean	SD
Age	7	0.47
Siblings	3.19	2.10
dmft	5.80	4.29
Decayed	5.73	4.25
Missing	0.07	0.38
Filled	0.00	0.10
DMFT	1.23	1.66
Decayed	1.21	1.64
Missing	0.02	0.14
Filled	0.00	0.04
TOCE	4.58	3.26

**Table 2** Model Results for Different Tooth Indices over Time and Across Group

	dmft		DMFT		Untreated Decay		TOCE	
	IRR	95% CI	IRR	95% CI	RR	95% CI	IRR	95% CI
Intervention group (versus control)								
Group 1	1.17	1.04–1.31	0.97	0.77–1.22	2.23	0.71–6.99	1.04	0.91–1.19
Group 2	0.93	0.83–1.04	1.02	0.82–1.27	1.45	0.51–4.09	1.01	0.88–1.16
Group 3	1.17	1.05–1.30	0.78	0.62–0.97	1.19	0.45–3.17	0.98	0.86–1.11
Age (time)	0.62	0.59–0.66	1.35	1.24–1.46	0.91	0.52–1.62	1.21	1.17–1.26

Results only shown for change over time and treatment group and not included confounders/covariates for each outcome.

RR, risk ratio.

untreated decay on any dentition (RR, 0.91; 95% CI, 0.52–1.62), though this latter finding was not statistically significant. In contrast, DMFT (IRR, 1.35; 95% CI, 1.24–1.46) and TOCE (IRR, 1.21; 95% CI, 1.17–1.26) both significantly increased over time. When compared with the control group, models for dmft and DMFT indicate that some experimental groups show a significant increase in the risk of decay while others show a significant decrease. For untreated decay, all groups showed increased risk of decay compared to a control group. However, model results for TOCE indicate that no groups were significantly different from the control group, and all point estimates were close to an expected rate of 1.

## Discussion

TOCE avoids bias due to exfoliation and can serve as an alternative measure of tooth decay in longitudinal, community-based, caries prevention studies. In evaluating TOCE, we compared multiple oral health indices to analyze a longitudinal, community-based caries prevention program. Findings indicated substantial differences in risk estimates across treatment groups and trends over time depending on the outcome used. In particular, differences in rate ratios for dmft and DMFT varied across groups and were statistically significant. Trends over time showed reduced risks for both dmft and untreated decay, despite the continued increase in the prevalence of untreated decay in permanent teeth. Age trends for both dmft and untreated decay were therefore biased by exfoliation of primary teeth, as primary tooth decay decreased from 95 percent at baseline to approximately 70 percent at the end of the study due to tooth loss. This indicates that the extent of bias depends on the ratio of primary to permanent decay at baseline. While DMFT was not biased by exfoliation, it underestimated the total amount of disease that was experienced due to ignoring the existing decay on primary dentition. In contrast, group rate ratios for TOCE were similar and not significantly different from the control group, and age trends showed a significant increased rate of total observed decay. Because TOCE accounts for all observed

decayed or filled teeth across both primary and permanent dentition, it more accurately reflects the total accumulated disease and is not biased due to tooth exfoliation.

TOCE is used as a discrete count outcome and can be analyzed using either Poisson or negative binomial regression in either a single level or multilevel model. If the mean and variance can be assumed to be equal, the Poisson model will provide better estimates of standard errors. Importantly, TOCE can be used even if study participants receive dental care outside of the study. For example, if a child presents with a filled tooth in a given observation but did not have a filling or carious lesion in the previous visit, TOCE would still increase despite not observing the actual untreated decay. As a result, TOCE is useful even for studies with unequally spaced or semi-infrequent observational periods.

As the prevalence of untreated decay in children in the United States – most recently estimated at 10 percent in children aged 2–5 years and 20 percent in children aged 6–8 years (12) – continues to persist, identifying the most efficacious preventive options for caries is paramount. Compared with TOCE, other common tooth indices may provide biased estimates of disease occurrence when used to evaluate community-based caries prevention programs. If exfoliated teeth are ignored when assessing the effects of preventive oral health care over time, both dmft and DMFT render biased estimates for dental health. When calculating TOCE, the informative missingness is accounted for and bias is avoided. This suggests that TOCE can be used to effectively evaluate longitudinal, community-based caries prevention programs.

## Acknowledgments

Research reported in this publication was supported by the National Institute of Dental and Craniofacial Research of the National Institutes of Health under award number R03DE025289. The content is solely the responsibility of the authors and does not necessarily reflect the official views of the National Institutes of Health. The authors would like to thank the anonymous referees for their assistance in reviewing this article.

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