

Long-term effects of a toddler-focused caries prevention program among Northwestern US tribal children: The TOTS-to-Tweens study

Nicole Holdaway Smith¹, Tam Lutz¹, Gerardo Maupomé², Jodi Lapidus³, Candice Jimenez¹, Maxine Janis⁴, Eli Schwarz³, Thomas Becker^{1,3}

Corresponding author: Nicole Holdaway Smith

2121SW Broadway, Ste 300

Portland, OR, 97201

Email: nsmith@npaihb.org

Office phone: 1.503.416.3292

Cell: 1.503.260.7367

Statement of author contributions:

Ms. Smith designed data collection instruments, protocols, collected data, performed all statistical analyses, was the lead in writing the manuscript, and approves this version for publication. Ms. Lutz, as co-Principal Investigator, contributed to the overall study design, designed data collection protocols, oversaw data collection at all sites, interpreted data, contributed to writing the manuscript and approves this version for publication. Dr. Maupomé designed the overall study, developed data collection protocols, advised on statistical analyses and outcome measures, interpreted data, contributed to the structure, writing, and revision of the manuscript and approves this version for publication. Dr. Lapidus contributed to study design, oversaw statistical analyses and interpretation of data, contributed to writing and critical revisions of the manuscript, and approves this version for publication. Ms. Jimenez was involved in planning and collecting data, advised manuscript content, and approves this version for publication. Dr. Janis advised the design of the data collection instruments and protocols, collected data, advised on data interpretation in the context of tribal communities, contributed content to the manuscript, and approves the manuscript for publication. Dr. Schwarz advised the design of data collection instruments and protocols, collected data, advised on interpretation in the context of global communities, contributed content to the manuscript, and approves the manuscript for publication. As Principal Investigator, Dr. Becker designed the overall study, generated hypotheses, approved data collection protocols, interpreted data, contributed substantially to manuscript writing, including how these data fit into the epidemiologic context, revised the manuscript, and approves this version for publication.

¹ Northwest Portland Area Indian Health Board

² Indiana University Richard M. Fairbanks School of Public Health

³ Oregon Health & Science University

⁴ Heritage University/Yakama Nation

Abstract

Objectives: We sought to determine if American Indian tribe-based interventions that successfully prevented toddler dental caries in a 2005 cohort study (the Toddler Overweight and Tooth Decay Prevention Study, or TOTS) influenced the prevalence of dental caries in children ages 11 to 13 in the same communities ten years later (the TOTS-to-Tweens study).

Methods: We recruited original TOTS participants and conducted school- and community-based dental screenings at tribal communities that received family plus community-wide interventions (F+CW), community interventions only (CW), or were control communities. We also enrolled children who did not participate in TOTS, but were exposed to CW interventions or to the control environment. Trained clinicians examined children's teeth and recorded whether each tooth was decayed, missing, or filled (DMFT). We calculated DMFT scores for each child and evaluated differences in DMFT Incidence Rate Ratios (IRR), and components of DMFT by intervention group.

Results: We observed lower age- and sex-adjusted DMFT scores among F+CW children (a mean of 2.1 DMFT; 95% confidence interval [CI]: 1.4-2.7), and among CW children (2.2; 95% CI: 1.9-2.6), than control children (3.0; 95% CI: 2.3-3.7). The F+CW group had 32% lower DMFT scores than control children (IRR=0.68; 95% CI: 0.46-1.01), and CW children had 26% lower DMFT scores than control (IRR=0.74; 95% CI: 0.55-1.00). The proportion of children with filled teeth was higher in control than intervention communities (37.9% in F+CW, 47.1% in CW, and 67.1% in control, $p=.002$).

Conclusions: Our findings suggest modest yet significant long-term effects of interventions that prevented toddler dental caries on the DMFT scores of tweens evaluated ten years later. Further study of effective interventions and their sustainability are clearly warranted among tribal children, who remain at high risk for dental caries.

Introduction

American Indian (AI) tribal populations in the US have a higher prevalence of dental caries in all age groups compared to the general US population,^{1,2} and the very high incidence of early childhood caries (ECC) has been documented in multiple surveys and studies.^{1,3,4,5,6} Equally troubling, caries appears to be common shortly after eruption of molars among AI third graders, with over one-third having caries in their permanent first molars.⁷ Fewer studies have assessed prevalence of caries in tribal pre-teens and teenagers, and those that have report high rates of caries and unmet dental care needs.^{8,9} Some efforts, including using fluoride mouth rinses,¹⁰ applying fluoride varnish,¹¹ and delivering health education and promotion interventions¹² have been widely demonstrated to prevent caries in both children and adolescents, and show promise for AI populations.^{13,14,15} Breastfeeding has been shown to prevent ECC,¹⁶ though it is less clear if the benefits extend to permanent teeth. Absent from a dental public health perspective are data that show the sustainability or long-term effectiveness of interventions that reduce caries among American Indian children, or if interventions that specifically prevent ECC also prevent caries in permanent teeth.

Our earlier cohort study, the Toddler Overweight and Tooth Decay Study (TOTS) (2003-2005), found that community and family interventions that promoted and supported breastfeeding, water consumption, and reducing sugared beverage consumption by families were feasible and effective at reducing dental caries incidence in two-year-old tribal children.^{17,18} The present TOTS-to-Tweens study aimed to determine if the lower average decayed, missing, and filled primary teeth (dmft) scores observed in TOTS intervention communities persisted in adolescence, or the 'tween' years (ages 11 to 13 years), in permanent teeth. We hypothesized that children who received community interventions would have lower decayed, missing, or filled permanent teeth (DMFT) scores than children from control tribes and that children who received the family intervention in addition to the community interventions would have the lowest DMFT scores of the three groups.

Materials and Methods

The TOTS study (2003-2005) recruited expectant mothers from five AI tribes in the Northwestern US. Tribes were assigned to receive: 1) community-wide interventions (CW); 2) family interventions in addition to CW activities (F+CW); or 3) no interventions, the control

condition (C). CW interventions used strategies to provide health education, augment public health practices, and modify environments and/or policies related to breastfeeding, sugar-sweetened beverages, and water consumption. Family interventions were delivered by community health workers using a home-visiting motivational interviewing model to a support breastfeeding, limit the introduction of sugared beverages to infants and toddlers, and promote water for thirst among toddlers.¹⁷ Two tribes implemented the F+CW interventions, one tribe implemented CW interventions only, and two tribes continued usual dental practices and care and served as comparison (control) communities.

Five Pacific Northwest sovereign tribal nations (“tribes”) participated in both TOTS and the TOTS-to-Tweens study. All tribes are members of the Northwest Portland Area Indian Health Board (NPAIHB) and are within the Portland Area Indian Health Service (IHS) area covering Idaho, Oregon and Washington states. Tribal councils gave permission for the research team to conduct the follow-up study and to access TOTS data. The study was reviewed and approved by the Portland Area IHS institutional review board (IRB00000645). Parent consent and child assent were collected from each study participant. Tribes had either an IHS or tribal health clinic that provided primary health care and dental care services to American Indians and Alaska Natives (AI/AN) in their service area. Intervention tribes had clinical user populations between 4100 and 5800 at the time of their participation in TOTS. Control tribes had clinic user populations of 1800 and 2500. All tribes experienced an increase in clinic user populations ten years later, from 3% to 37%. Each tribe had dental programs that employed dentists, dental assistants and dental hygienists to deliver care including hygiene, sealants, fluoride, and urgent care. One F+CW tribe and one CW tribe provided community water fluoridation; the remaining three tribes did not fluoridate local water. No changes in community water fluoridation took place within any of the tribes during the ten-year interval between TOTS and TOTS-to-Tweens.

For the TOTS-to-Tweens study, we defined three groups of children based on exposure to the components of the TOTS interventions.

Group 1: Family + Community-wide intervention group (F+CW), consisting of children from two tribes that received family and community interventions and participated in TOTS ten years earlier.

Group 2a: Community-wide intervention group (CW), consisting of children from the CW intervention tribe, regardless of whether we examined their teeth at age two years in TOTS.

Group 2b: Children from F+CW intervention tribes who did not receive family interventions or contribute data to TOTS, but had exposure to CW interventions implemented as part of TOTS.

We combined groups 2a and 2b for analysis.

Group 3: Control tribal children (C), consisting of children from two TOTS control tribes, regardless of whether we examined their teeth at age two years in TOTS.

We scheduled school and community-based dental screenings at each tribe. Site coordinators used TOTS participant lists to contact parents or guardians for consent for their child to participate in TOTS-to-Tweens and school and clinic user lists to identify and recruit children age 11 to 13 years who did not participate in TOTS. At the screening, we verified parental consent and obtained each child's assent to have teeth examined, to have height and weight measured, and to complete an oral health questionnaire.

Two dental practitioners were trained prior to data collection and their agreement of dental assessments was calibrated at the first screening. We adapted the World Health Organization (WHO) oral health assessment form for children¹⁹ and collected tooth-level data for both primary and permanent teeth. Examiners used a tongue depressor and mirror to examine children's mouths and verbally provided tooth codes to recorders. A tooth was scored as unerupted, sound, caries present, filled (w/caries), filled (no caries), missing, sealed, or fixed dental prosthesis. No radiographs were taken and no treatment was offered. Letters stating the examination results were sent home to parents or guardians and site coordinators directed messages to providers when urgent treatment needs were noted. Trained investigators measured children's height and weight using a medical-grade stadiometer and scale that was calibrated at each data collection site. We administered a questionnaire adapted from WHO Oral Health Questionnaire for Children,¹⁹ and asked children about hygiene practices, dental pain, tobacco use, and types and frequency of beverage consumption.

We calculated DMFT score (the sum of decayed, missing, and filled teeth) for each child and assessed differences in DMFT scores by intervention group using a statistical model appropriate for count data, negative binomial regression. This strategy accounted for the observed over-

dispersion (larger variance than mean) in DMFT, which cannot be adequately accommodated by Poisson regression. We also modeled DMFT as a binary outcome (DMFT=0 vs. DMFT>0) using log-binomial models with the Poisson approximation, to assess whether the proportion of children with all sound teeth differed by intervention group. We modeled each component of DMFT similarly, via both count and binary models. All models included an offset term to account for different numbers of permanent teeth per child. We included children's age and sex in the models to account for potential distribution differences by intervention group. Girls' teeth often erupt earlier, and older children's teeth may have had more opportunity for caries, so we adjusted for these factors to appropriately evaluate intervention effect. Adjusted incidence rate ratios (IRRs) for each intervention group vs. control from models are presented, as well as marginal means or proportions for factors in the models.

Because tribes had differing water fluoridation practices, we constructed additional models that adjusted for community water fluoridation status as a binary measure. Also, since a few children had mixed dentition, we repeated our analyses with DMFT plus decayed, missing, or filled primary teeth (dmft) as the outcome.

We performed all analyses in Stata version 15 (StataCorp. 2017. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC).

Results

We performed dental exams and collected child questionnaires from 335 children. Site coordinators recruited 45% of the 299 original TOTS cohort; response rates varied from 32% to 56% by tribe. Most of the loss to follow-up was due to families moving from the area; we verified this for 15% of children, but were unable to contact 35% of original TOTS participants after multiple attempts. The remaining 5% loss to follow-up included three individuals who declined to participate, one deceased child, and eleven children who agreed to the examination but did not attend the screening. Of the children we contacted who did not participate in original TOTS, but were exposed to the community interventions or to the control environment, 93% agreed to participate in this study. These children comprised 62% of our total study participants.

Child age and gender distributions differed by intervention group, with a higher proportion of 13-year-old children and girls in the control group. Body Mass Index (BMI)-for-age percentiles were also different by intervention group, with a greater proportion of control community children in the healthy BMI-for-age group (Chi-square $p=.014$).

Table 1. Characteristics of children by intervention group, TOTS-to-Tweens study

	Family + Community Intervention (n=62)	Community Intervention (n=187)	Control (n=86)
	n (%)	n (%)	n (%)
Age (years)			
11	28 (45%)	82 (44%)	17 (20%)
12	32 (52%)	83 (44%)	25 (29%)
13	2 (3%)	22 (12%)	44 (51%)
Sex			
Male	30 (48%)	100 (53%)	32 (37%)
Female	32 (52%)	87 (47%)	54 (63%)
Body Mass Index for Age^a			
Healthy (5th to <85th percentile ^b)	13 (21%)	57 (31%)	34 (40%)
Overweight (85th to <95th percentile)	14 (23%)	33 (18%)	24 (28%)
Obese (\geq 95th percentile)	35 (56%)	95 (51%)	28 (33%)

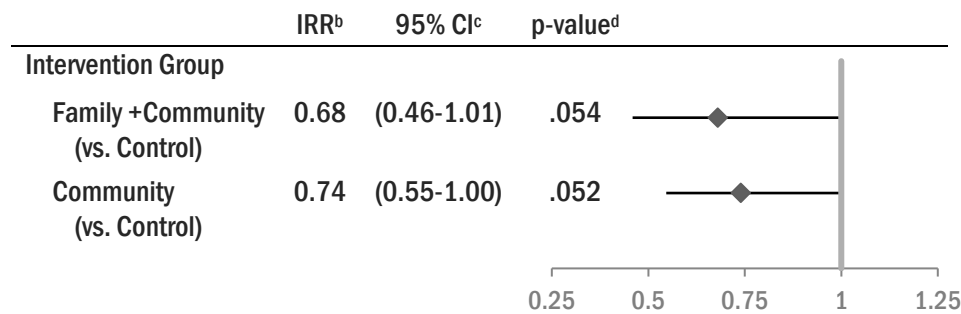
^aBody Mass Index (BMI) calculated as ((weight in pounds)/(height in inches²))*703

^bBMI percentiles assigned using the World Health Organization BMI values for child age and sex

Our primary outcome, DMFT score, differed by intervention group. CW children had 26% lower DMFT scores than control children, and children who had received the family intervention had 32% lower DMFT scores than control (see Figure 1). Child age was not strongly related to DMFT scores (IRR=1.04, $p=.663$), and girls had marginally higher DMFT counts than boys (IRR=1.24, $p=.094$). When we controlled for community fluoridation status in the model, intervention group became more strongly associated with DMFT scores (IRR for F+CW vs. control=0.58, $p=0.012$, and IRR for CW vs. control=0.58, $p=.007$). Community water fluoridation status itself was not statistically related to DMFT, but its inclusion in the model

increased the magnitude of the intervention effect. DMFT in primary and permanent teeth (DMFT+dmft) was also different by intervention group (IRR for F+CW vs. control=0.65, $p=0.022$, and IRR for CW vs. control=0.74, $p=.041$). No other factors, including BMI-for-age percentiles and information collected in the child questionnaire, were statistically related to DMFT scores.

Figure 1. DMFT^a incidence rate ratios and 95% confidence intervals by intervention group, adjusted for child age and sex and accounting for permanent teeth count, TOTS-to-Tweens study



^aDecayed, Missing, or Filled Teeth

^bIncidence rate ratio

^cConfidence interval

^dFor intervention group in negative binomial regression model

DMFT as a binary variable (DMFT=0 vs. DMFT>0) was marginally different by intervention group. Girls were less likely to have all sound teeth than boys (IRR=0.71, $p=.047$), and girls from control tribes were the least likely to have all sound teeth. Children from control tribes had higher mean DMFT scores, a higher proportion of children with one or more fillings, and a higher mean number of filled teeth than either intervention group. While a greater proportion of control children had untreated caries than CW or F+CW children, this finding was not statistically significant.

Table 2. Dental measures of tribal children age 11-13 years by intervention group, adjusted for child's age and sex and offset by permanent teeth count, TOTS-to-Tweens study

	Family + Community Intervention (n=62)		Community Intervention (n=187)		Control (n=86)	
	% or mean	95% Confidence Interval	% or mean	95% Confidence Interval	% or mean	95% Confidence Interval
DMFT^a						
Percent of children with DMFT score of 0	35.3%	(23.1-47.6)	32.7%	(25.8-39.6)	22.8%	(13.3-32.3)
Boys	41.7%	(26.0-57.5)	38.7%	(29.2-48.2)	26.9%	(14.8-39.1)
Girls	29.7%	(17.9-41.4)	27.5%	(19.4-35.6)	19.1%	(10.7-27.5)
Mean DMFT scores	2.1	(1.4-2.7)	2.2	(1.9-2.6)	3.0	(2.3-3.7)
Boys	1.8	(1.2-2.4)	2.0	(1.6-2.4)	2.7	(1.9-3.5)
Girls	2.3	(1.5-3.0)	2.5	(1.9-3.0)	3.3	(2.5-4.2)
Decayed teeth						
Percent of children with decayed teeth	40.2%	(28.6-51.7)	36.1%	(29.3-42.9)	46.0%	(34.1-58.0)
Mean number of decayed teeth	1.3	(0.7-2.0)	1.1	(0.8-1.5)	1.2	(0.7-1.7)
Filled teeth						
Percent of children with filled teeth ^b	37.9%	(25.6-50.2)	47.1%	(40.0-54.2)	67.1%	(56.2-78.0)
Mean number of filled teeth ^c	0.9	(0.6-1.3)	1.2	(0.9-1.5)	1.9	(1.3-2.4)
Missing teeth						
Percent of children with missing teeth	1.6%	(0.0-4.8)	3.8%	(1.0-6.6)	9.0%	(2.2-15.7)
Mean number of missing teeth	0.02	(0.00-0.05)	0.05	(0.01-0.09)	0.15	(0.02-0.28)

^aDecayed, Missing or Filled Teeth

^bStatistically significant difference between intervention groups in log-binomial model F+CW vs. C p=.002, CW vs. C p=.002, F+CW vs CW p=.243

^cStatistically significant difference between intervention groups in negative binomial model F+CW vs. C p=.006, CW vs. C p=.025, F+CW vs CW p=.292

The proportion of children with any sealants on permanent teeth was not statistically different by intervention group, with 68% of control children (95% CI: 58%-79%), 76% of CW children (95% CI: 69%-82%) and 77% of F+CW children (95% CI: 67%-87%) having one or more sealed teeth. A greater proportion of children from control tribes reported cleaning their teeth two or more times per day (71%; 95% CI: 61%-81%) than CW children (40%; 95% CI: 33%-47%) and F+CW children (36%; 95% CI: 23%-48%). Drinking sugar-containing soda every day was also more commonly reported by control children (19%; 95% CI: 10%-27%) than CW (12%; 95% CI: 8%-17%) or F+CW children (5%; 95% CI: 0%-10%). Neither reported hygiene frequency nor daily soda consumption was related to DMFT score.

Discussion

AI tribes with a high incidence of toddler caries implemented interventions to increase breastfeeding initiation and duration, delay the introduction of sugared beverages to babies and toddlers, and promote water consumption. Post-intervention, less tooth decay was observed in two-year-old children who had received interventions than toddlers in the same community pre-intervention, and intervention children had lower dmft scores than children from control tribes. When we returned to the same tribes ten years later and performed dental examinations, children age 11 to 13 years who had received F+CW interventions as babies and those who had received CW interventions had lower caries experience in permanent teeth (DMFT) than control tribal children. These findings suggest that the original TOTS interventions may have had a modest long-term effect on caries occurrence in adolescence, in the absence of any concerted effort to sustain intervention activities. The CW and family interventions potentially being equally effective reflects the fact that community, political and social environments have the potential to support individual behavior change and contribute to improved health community-wide.

While the observed IRRs were modest, adjusting for community water fluoridation status strengthened the intervention effect, as did assessing caries and fillings in both primary and permanent teeth. We do not think DMFT differences were due to different access to dental treatment or preventive care. Children in all groups had received dental care, as evidenced by the majority of children having one or more sealants on permanent teeth (68% to 77% by intervention group) and that a substantive proportion of the difference in DMFT scores by group can be attributed to fillings, rather than untreated caries.

Our loss to follow-up of original TOTS participants was high (55%), since many children no longer lived in the area. This limited our ability to conduct within-child analyses that controlled for dmft scores at age two. Instead, we structured our analysis at the intervention level, which was more practical and appropriate given the community nature of the original interventions. For consistency, we used two dental examiners who traveled to tribes to collect study data. A drawback of this method is that children had to be available during the short data collection period. Using dental clinic staff as examiners could have extended the data collection window and potentially increased the opportunity to include original TOTS children in the follow-up

study, though this would have introduced potential examiner variation. We did not re-train examiners or recalibrate exams, and it is possible that examiner drift occurred over the course of the study. Given our scope, we did not evaluate factors known to cause caries (microbiologic, dietary, cultural, social, economic) in relation to our original interventions and to dental outcomes. This would best be done in a prospective cohort study. Even if we cannot attribute observed DMFT differences to original TOTS interventions, we must acknowledge that there are clear patterns in caries experience that vary by community. The evidence that intervention group was the most important factor related to DMFT –not body mass index or reported hygiene practices, for example – is noteworthy. These community-level factors, whether environmental, cultural, or clinical, are important for oral health and should be explored.

Identifying effective interventions to address dental health in AI/AN children is critically important given the oral health disparities experienced by this population. Although caries experience in our study was better for intervention tribal children (65% to 67%) than for control tribal children (77%), figures were still worse than the mainstream US population. The National Health and Nutrition Examination Survey reported that in 2011 to 2012, 29% of children age 9 to 11 and 50% of children age 12 to 15 had experienced caries in permanent teeth, so even intervention children in our study experienced more caries than the general population of children their age.²⁰ These figures are concerning and are similar to findings from other tribal groups.^{4,7} Phipps reported that two-thirds of AI/AN students aged 13 to 15 had a history of caries in their permanent dentition, which is the same as our intervention children.²¹ The AI/AN oral health disparity has also been reported for untreated caries, with AI children having triple the proportion of untreated caries as all US children aged 5 to 19 years (55% tribal vs. 17% nationally).²² In our region of the country, the Washington State Smile survey found that AI second and third graders were twice as likely to have untreated caries in any teeth than white children the same age (19% vs. 10%); AIs were the most likely of all racial or ethnic groups in Washington to have widespread caries and urgent dental needs.²³ Though untreated caries may not have been statistically different by intervention group in our study (36% to 46%), it was high, comparable to the levels found by Phipps et al. in AI middle school students (38%),²¹ and much higher than 12 to 15 year old children in the general US population (15%).²² Other studies, including TOTS, have reported higher DMFT scores among children with very low and/or very high BMI-for-age percentiles,²⁴ and though our control children had higher DMFT scores and

lower BMI-for-age percentiles than either intervention group, we did not find a relationship between BMI and caries experience.

The higher caries experience in AI/AN children may be due to a variety of behavioral, bacterial and environmental factors. Behaviors that foster the establishment of a favorable microbiota early in life, including breastfeeding and water consumption, may impact oral and overall health long-term. Our findings suggest that creating an environment that supports those behaviors may be equally important to promoting individual behaviors and providing clinical services. While observing lower DMFT scores among children who received interventions is encouraging, we studied only a few tribes within the Pacific Northwest, so similar studies must be carried out in other AI communities to validate our findings. Most caries intervention studies in AI/AN communities reported over the past decade have not been very successful, though motivational interviewing, similar to the TOTS family intervention, has been effective at increasing other health-promoting behaviors among AI/AN.^{15, 25, 26} A promising practice for AI/AN tribes is the Dental Health Therapy Aide model (DHAT),²⁷ where mid-level providers are trained to provide culturally competent routine preventive and restorative services as part of a dental team. In the context of our findings, DHATS, dentists, and other clinical experts may increase their community impact by addressing water quality, community water fluoridation, breastfeeding, food systems, health education and focused family goal setting. Tribal initiatives aimed at preventing ECC that utilize community-wide strategies could have lasting benefits for tribal children.

Summary: Our findings suggest that community-level factors and community and family level interventions are important to a child's dental health. Implementing such interventions may yield long-term benefits, which is especially encouraging for communities with limited resources. The oral health status of tribal children in the Northwest and nationwide must be viewed as a public health priority. Efforts to positively impact dental health, including long-term evaluations of interventions such as our original TOTS intervention, are encouraged. We hope that other research groups will carry out similar caries intervention studies and report on lasting effects of those interventions, to further inform work to improve oral health of tribal children.

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Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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