Community Dental Health (2006) **23**, 244-250
Received 22 March 2004; Accepted 31 October 2004

Relationship between dental caries experience (DMFS) and dental fluorosis in 12-year-old Puerto Ricans.

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Objectives: Examine the relationship between (1) DMFS and community fluorosis index (CFI) scores, and (2) between individual DMFS and NIDR/Dean Index fluorosis scores. ***Design:*** Population-based, cross-sectional study. ***Setting:*** Public and private schools of Puerto Rico. ***Subjects:*** 1,435, 12-year old students. ***Method:*** A probabilistic stratified sample was selected from 11 regions of Puerto Rico, according to type of school (public and private), and setting (urban and rural). Children were examined using NIDR criteria for DMFS and fluorosis. Regressions examined the relationship between DMFS means and CFI scores. Individual level DMFS was regressed on NIDR/Dean Index scores to test for linear and deviation from linear trends**.** ***Results:*** **(**1) There was no statistically significant relationship between regional DMFS and CFI scores, and (2) individual level fluorosis scores when dichotomized as 0-2 as the referent level to level 3-4 demonstrated a statistical significant higher DMFS with the higher fluorosis level. Gender and school setting were statistically significant in all models: females and public school attendance were associated with increased DMFS. ***Conclusion:*** No ecological relationship between CFI and DMFS scores was found in 12-year-old children in Puerto Rico. Moderate and severe fluorosis were associated with higher DMFS levels relative to lower fluorosis scores, though this finding may be associated with restorations placed for cosmetic reasons. While controlling severe fluorosis is desirable, this will have little impact on overall high caries in Puerto Rican children. These findings suggest caution when interpreting caries experience using the DMFS index in populations with differing fluorosis levels.

Key words: children, cross-sectional study, Dean Index, dental caries, dental fluorosis,, DMFS, Puerto Rico, 12 year olds

Introduction

The introduction of fluoride in its multiple forms as an anticariogenic agent has produced a marked reduction of caries in the United States and internationally. Decreasing caries levels reported in countries without systemic fluoridation programmes may be attributed to fluoridated dentifrices and the implementation of supervised programmes such as fluoridated mouthwashes and topical application of fluoride gel. Additionally, fluoride incorporated in food and drink products produced in fluoridated areas may, through their importation, add to the population exposure of fluoride in non-fluoridated communities (Levy *et al*., 1995). In the United States and other countries with developed market economies, the difference in the prevalence of caries among communities with optimally fluoridated water relative to areas having water fluoride deficiencies has been documented (Burt, 1994; NIDR, 1989; Mandel, 1996). Fluoride may have a greater dental caries preventive impact in lower socioeconomic communities, underscoring its continuing public health importance (Reisine & Psoter, 2001).

The reported prevalence of dental fluorosis has ranged from 2.9 to 41.8 percent in non-fluoridated communities (Clark, 1994; Pendrys *et al*., 1996) and from 45 to 81 percent in areas with optimal water fluoridation programs (Clark, 1994; Williams & Zwemer, 1990). Several authors have reported an increase in the prevalence of dental fluorosis, mainly in the mild categories, concomitant with the reduction of dental caries (Pendrys *et al*., 1996; Szpunar & Burt, 1987; Williams & Zwemer, 1990). Investigators have also reported that in individuals with very mild or mild fluorosis, there is less risk for dental caries relative to individuals having no fluorosis. This has been observed both in communities with and without fluoridation programmes (El-Nadeef & Honkala, 1998; Hawley *et al*., 1996; Songpaisan & Davies, 1989).

In 1997 the P.R. Health Department reported natural water fluoride levels in the ≤ 0.2 ppm range with rare instances of 0.4 and 0.5 ppm. Water fluoridation was instituted in Puerto Rico during the years 1953 and 1954. However, during the latter part of the 1980's, water fluoridation was discontinued due to budgetary constrains. Dental caries levels in Puerto Rico are among the highest in the Caribbean, with a national 12 year-old DMFS of 6.4 (Elías-Boneta *et al*., 2003). The contemporary relationship between caries and dental fluorosis in Puerto Rico is unknown. Understanding the relationship between dental caries and dental fluorosis in Puerto Ricans is important for the design and implementation of primary dental caries prevention programmes on the Island.

The specific aims of the present analysis of 12-year-old Puerto Ricans were two-fold:

1. to examine the ecological correlation between DMFS prevalence and community dental fluorosis index (CFI)
2. to examine the relationship between individual DMFS and a modified Dean Index score for dental fluorosis.

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Methods

Sample Design:

The study design and sampling have been described previously (Elías-Boneta *et al*., 2003). Briefly, a cross-sectional, nationally representative oral health study of Puerto Rican 12-year olds was conducted in 1997. A probabilistic stratified sample of public and private schools were selected from the eleven health administrative regions of Puerto Rico, according to the type of school (public or private) and urban vs. rural status. In ten regions, five public schools and one private school were selected, and in the Northern region ten public and five private schools were selected. Four trained and calibrated investigators examined a total of 1,435 12-year-old Puerto Rican children for DMFS (decayed, missing due to caries, and filled surfaces and dental fluorosis). The study was approved by the Institutional Review Board of the Medical Sciences Campus of the University of Puerto Rico.

Caries and fluorosis criteria:

DMFS and fluorosis were defined and measured using the NIDR/ Dean diagnostic criteria, described by the National Institute of Dental Research (NIDR, 1991), currently NIDCR and based on the Dean Index for dental fluorosis. For the initial, ecological analysis, DMFS was converted to DMFS rates per 100 children, and the Community Fluorosis Index (CFI) was used for the eleven Health regions of Puerto Rico. The CFI calculates the arithmetic mean for a geographic region, based on the results from the NIDR/Dean Index of the individuals. According to Dean (1946), a CFI score of 0.6 or higher indicates "a public health problem" The NIDR/Dean Index scores fluorosis as 0 for no fluorosis, 0.5 for questionable fluorosis, 1 very mild fluorosis, 2 mild fluorosis, 3 moderate fluorosis, and 4 for severe fluorosis. The diagnostic sign for severe fluorosis is discrete or confluent pitting of enamel. These scores are numerically different though directly analogous to World Health Organization criteria (WHO, 1997) (scored 0, 1, 2, etc). Statistical analyses aggregated the questionable, i.e., indeterminate, 0.5 category with no fluorosis.

Covariates:

Stratification was conducted in the eleven health administrative regions of Puerto Rico, according to type of school and socio-economic status determined in (1) public schools by the percentage of residents under poverty levels and in (2) private schools by tuition rates, and setting (urban vs. rural status). Gender and public vs. private school status were incorporated into the multivariable modeling as potential confounders. Public/private school attendance was used as a surrogate for socioeconomic status (SES) level.

Data analysis:

The statistical software SUDAAN, which takes into account the complex sampling methodology was used to analyze health region DMFS per 100 children and regional CFI scores, as well as for the individual level regression analyses. CFI was used as a proxy for past fluoride exposure at the community level. Dean Index fluorosis scores were used as a proxy for past fluoride exposures at the individual level. The validity of the Dean Index as a proxy for past fluoride exposures is limited because fluoride exposure after the 6-8 years old period will not be reflected as enamel fluorosis.

1) The ecological correlations between DMFS per 100 children and CFI of the eleven health regions of Puerto Rico were determined as follows. The individual DMFS scores were converted to DMFS/100 children/ health region and the fluorosis scores (NIDR/Dean Index) were converted to regional CFI scores. Four regression analyses were conducted, i.e. linear and exponential rate models were fitted to model DMFS/100 regressed on CFI assuming both Gaussian and Poisson distributions (SAS, Genmod).

2) The relationship between DMFS and fluorosis scores (NIDR/Dean Index) at the individual level analysis was determined as follows. To normalize the DMFS distribution, we used the square root of DMFS. The square root of DMFS scores was then regressed on the NIDR/Dean Index scores, controlling for gender and public/private school type (SES surrogate). The complex sampling design was accounted for in the modeling, which considered stratification, clustering and individual probability weights (SUDDAN, robust variance, using both independent and exchangeable correlation structures). Linear and non linear trends were evaluated through the use of three models in which the individual NIDR/ Dean fluorosis score treated as: 1) continuous variable, 2) "dummy" variables, and 3) a dichotomous variable (NIDR/Dean score <3 and ≥ 3).

Results

Nationally, thirty-two percent of the weighted sample of 12 year olds presented with NIDR/Dean fluorosis scores of one or greater (WHO scores of 2 or greater), while ten percent had scores of two or higher (Table 1). Intra-examiner Kappa statistic values ranged from 0.90 to 0.97 for caries and 0.80 to 0.90 for dental fluorosis. Inter-examiner values ranged from 0.88 to 0.96 for caries and 0.76 to 0.86 for dental fluorosis when compared to the reference examiner.

Ecological Analysis:

Across the regions DMFS per 100 children ranged

Table 1. Distribution of NIDR/Dean fluorosis scores of 1,435 Puerto Rican 12-year-olds, weighted percent representing 71,358 children

*Dean Fluorosis Score**	*n*	*Percentage ** *	*SE of %*
0	869	0.68	0.017
1	393	0.23	0.014
2	125	0.07	0.007
3	33	0.02	0.004
4	15	0.01	0.003

* NIDR/Dean fluorosis scores of 0.5 aggregated in the zero category

** Percentage for population weighted N

from 525 to 920, and CFI scores ranged from 0.03 to 1.26 (Table 2). No ecological regression model was statistically significant at the 0.05 level. The observed p-values were 0.726 (linear Gaussian), 0.732 (exponential Gaussian), 0.066 (linear Poisson), and 0.073 (exponential Poisson). Figure 1 visually demonstrates the absence of a relational DMFS rates/CFI trend at the regional level. In non-fluoridated Puerto Rico, there was no statistically significant relationship between regional DMFS means and CFI scores.

Individual level analysis:

Table 3 presents the mean DMFS and mean of the square root of the DMFS scores by NIDR/Dean Fluorosis Index scores. Figure 2 graphically demonstrates a clear increase in mean DMFS levels at fluorosis scores of 3 and 4.

The relationship between the mean square root of DMFS and fluorosis scores failed to demonstrate a linear relation-

Table 2. CFI and DMFS/100 children rate, by health region, Puerto Rico, 1997

Health Region	*Sample n*	*% Total n*	*Weighted n**	*% Total Weighted n**	*CFI***	*DMFS per 100 children****
Metropolitan	121	8.4	12,465	17.5	0.03	528.6
North	267	18.6	10,820	15.2	0.13	537.4
East	119	8.3	5,298	7.4	0.18	649.0
Mountain	143	10.0	12,182	17.1	0.41	920.4
San Juan	132	9.2	8,881	12.4	0.51	557.0
Northeast	108	7.5	3,318	4.7	0.76	762.8
Southeast	115	8.0	4,991	7.0	0.74	644.1
West	89	6.2	3,296	4.6	0.83	524.7
Northwest	101	7.0	3,421	4.8	1.17	743.3
Ponce	121	8.4	4,133	5.8	1.01	606.4
Southwest	119	8.3	2,547	3.6	1.26	577.3
Total Puerto Rico	1,435	100.0	71,352	100.0	0.46	641.0

* Percentage for population weighted n
** for population weighted n, NIDR/Dean fluorosis scores of 0.5 aggregated in the zero category
*** for population weighted n

Table 3. NIDR/Dean Fluorosis Index scores and means of the square root of DMFS and DMFS, 1,435 12-year-old Puerto Rican children, 1997

*NIDR/Dean Fluorosis Index store**	*Mean of the square root of DMFS*	*DMFS*
0	2.11	6.43
1	2.06	6.15
2	2.18	7.03
3	2.72	9.93
4	2.68	9.29

* 0.5 scores aggregated with 0 scores

Table 4. Linear Regression for individuals*, NIDR/Dean Fluorosis as continuous variable, correlation structures independent and exchangeable, response variable: square root of DFMS

	Independent Correlation		*Exchangeable Correlation*	
Predictors	*β (SE)*	*p-value*	*β (SE)*	*p-value*
Intercept	1.55(0.12)		1.52(0.13)	
School type-**	0.49 (0.15)	0.001	0.51 (0.15)	0.001
Gender***	0.28 (0.09)	0.003	0.27(0.08)	0.001
Fluorosis values****	0.07 (0.05)	0.175	0.06(0.05)	0.249
	Multiple R^2= 0.029		Multiple R^2= 0.029	

* Robust Variance Estimation
** Referent: private school
*** Referent: male
**** 0.5 scores aggregated with 0 scores

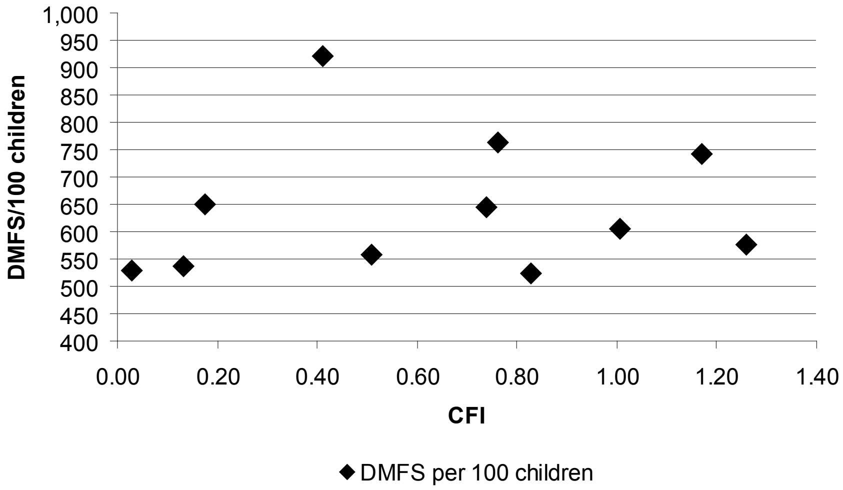

Figure 1. *DMFS/100 children by CFI, for eleven health regions, Puerto Rico, 1997*

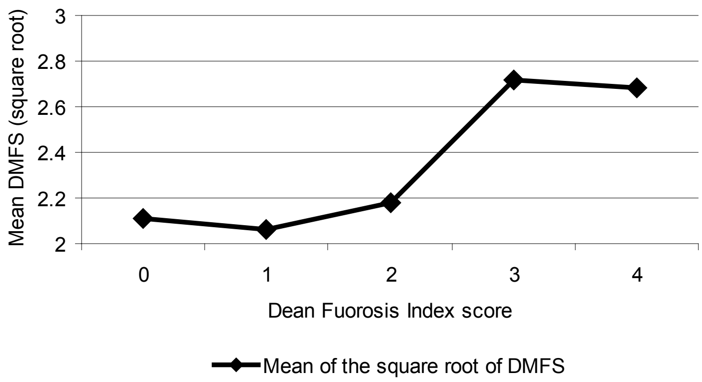

Figure 2. *Mean of the square root of DMFS vs. NIDR/Dean fluorosis Index*, 1,435 12-year-old Puerto Rican children, 1997*

(*0.5 scores aggregated with o scores)

ship (p=0.175 and 0.249) for independent and exchangeable correlation structures, respectively (Table 4). To test for a non-linear trend, the fluorosis scores were treated as categorical dummy variables. These models suggested a threshold effect at fluorosis level 3 (p=0.052), independent correlation structure, and 0.065, exchangeable structures (Table 5). Fluorosis scores were then dichotomized at <3 (the referent category) and 3-4. This final model demonstrated a statistically significant positive association between fluorosis scores and higher DMFS level (p=0.005 and 0.009, for independent and exchangeable correlation structures, respectively) (Table 6). Gender (girls) and public school attendance were statistically associated with increased caries levels in all models.

The robustness of the findings is suggested by ecological analyses that did not aggregate the 0.5 fluorosis category with the 0 fluorosis group and produced virtually identical results.

Discussion

This national cross-sectional study of 12-year-old children in Puerto Rico found that meaningful dental fluorosis was present in 32 percent of the children. Further, this population has a high caries burden with a mean DMFS of 6.4. The ecological analysis in the present study did not find an association between DMFS/100 children and the Community Fluorosis Index for the Health Regions in Puerto Rico, a non-fluoridated country. Similar results were reported in New York on a study involving 3,500 children from fluoridated and non-fluoridated communities and concluded that there was an inconsistency in the relationship between caries and dental fluorosis (Kumar & Swango, 1999*)* in areas where children are exposed to fluoride from multiple sources.

At the individual level of the analysis, there was no linear correlation between fluorosis levels and DMFS. However, the sample of those with fluorosis scores of 3 and 4 (composed of forty-eight children representing three percent of the 12 year olds in Puerto Rico) revealed, a statistically significant threshold effect in which DMFS was positively associated with moderate and severe fluorosis scores. No relationship between DMFS and NIDR/Dean fluorosis scores was evident when children with fluorosis levels 3 and 4 were excluded from the analysis.

The findings of this investigation suggest that, even in areas having very low water fluoride levels, fluoride is ingested in quantities sufficient to result in a range

Table 5. Linear Regression for individuals*, NIDR/Dean Fluorosis score as "dummy" variable, correlation structures independent and exchangeable, response variable: square root of DFMS

	Independent Correlation		*Exchangeable Correlation*	
Predictors	*(SE) β*	*p-value*	*(SE) β*	*p-value*
Intercept	1.57 (0.13)		1.55 (0.14)	
School Type**	0.50 (0.15)	0.001	0.53 (0.16)	0.002
Gender***	0.28 (0.09)	0.003	0.27 (0.08)	0.001
Fluorosis values****				
Fluorosis 1	-0.08 (0.08)	0.354	-0.14 (0.08)	0.086
Fluorosis 2	0.03 (0.15)	0.814	-0.01 (0.13)	0.929
Fluorosis 3	0.61 (0.31)	0.052	0.62 (0.33)	0.065
Fluorosis 4	0.55 (0.39)	0.165	0.48 (0.40)	0.23
	Multiple R^2 = 0.033		Multiple R^2= 0.033	

* Robust Variance Estimation
** Referent: private school
*** Referent: male
**** Reference value: 0 (0.5 scores aggregated with 0 scores)

Table 6. Linear Regression for individuals*, NIDR/Dean Fluorosis score as dichotomized variable, correlation structures independent and exchangeable, response variable: square root of DFMS

	Independent Correlation		*Exchangeable Correlation*	
Predictors	*β (SE)*	*p-value*	*β (SE)*	*p-value*
Intercept	1.56 (0.12)		1.53 (0.13)	
School Type**	0.50 (0.15)	0.001	0.51 (0.15)	0.001
Gender***	0.28 (0.09)	0.003	0.27 (0.08)	0.001
Fluorosis values ****	0.61 (0.21)	0.005	0.61 (0.23)	0.009
	Multiple R^2 = 0.033		Multiple R^2= 0.033	

* Robust Variance Estimation
** Referent: private school
*** Referent: male
**** Referent: 0, 1 and 2 from NIDR/Dean Index (0.5 scores aggregated with 0 scores)

of dental fluorosis, including moderate and severe levels for some members of the community. The source and timing of such exposures was not explored in this study. Within the limits of this investigation, increasing levels of fluorosis were not associated with caries diminution at either the population or individual level.

While many studies assessing the relationship between high water fluoride levels and dental caries at the community level have shown beneficial effects, there are studies showing no discernable benefits above 1 ppm (Angelillo *et al*., 1999;Lewis *et al*., 1992; Yoder *et al*., 1998; Warnakulasuriya *et al*., 1992). In studies conducted at the individual level (person level score and DMFT/DMFS) mixed findings have been reported regarding the association between dental fluorosis and caries (Cortes *et al*., 1996; Ermis *et al*., 2003; Warnakulasuriya *et al*., 1992; Wondwossen *et al*., 2004). Eklund and Burt failed to find an excess risk in adults using stratified and multivariate analyses. In fact, they found a protective effect in molars in a high fluoride area.

Several possible interpretations can be made based upon our findings. These findings suggest severe fluorosis may be a risk factor for increased DMFS in individuals living in communities without fluoridation programmes. Children at risk of more severe dental fluorosis in Puerto Rico may also be at an elevated risk of higher DMFS levels for reasons undeterminable from these data.

A second consideration is that fluoride exposure timing may be different for caries protection and dental fluorosis risk in this population. Relatively consistent systemic fluoride exposure at appropriate fluoride levels is necessary for a caries protective effect while tooth susceptibility to fluorosis may be less sensitive to exposure consistency (Pendrys *et al* 1996). Third, caries could have occurred on teeth with limited fluoride exposure, while a later fluoride exposure could have increased fluorosis scores on latter erupting teeth. In addition, these findings suggest that severe fluorosis may be a risk factor for either increased caries or restorations placed for cosmetic or misdiganostic reasons.

Limitations of this investigation need to be weighted in any interpretation of these findings. First, NIDR/Dean Index scores were used as a surrogate measure for fluoride ingestion. Neither the fluoride exposure nor the timing of any exposure were ascertained, thus fluoride exposure may be misclassified. Further, fluoride exposures between ages eight through 12 would not be reflected in enamel fluorosis. Secondly, the community level analysis is subject to the ecological fallacy, i.e. what is seen at the community is not necessary indicative of what occurs at the individual level. Third, the limited number of moderate and severe fluorosis cases may have limited the power to detect a linear trend, though we note that a deviance from linear trend was found**.** The clinical reason for restoration placement is unknown; thus interpreting the filled component as caries may be inaccurate. An additional limitation of this study is the delineation of geographic regions. That is, health administrative regions were utilized, which though in broad terms represent relatively distinct areas, may be subject to misclassification in terms of similarity of communities included in each region.

The individual level analysis is also subject to the limitation of utilizing NIDR/Dean Index scores as a fluoride exposure surrogate measure. However, the findings of this investigation suggest that dental fluorosis in its more severe form (discrete or confluent pitting) is associated with increased DMFS. This enamel defect has been previously proposed with the specific biological mechanism being that an increased tooth surface irregularity provides an environment for cariogenic plaque retention and the associated difficulty with keeping them clean (El-Nadeef & Honkala, 1998); Driscoll *et al*. reported this association in the US. However, a study in adults by Eklund *et al*. that used a multivariate analysis failed to confirm these findings. The National Research Council (2006) has stated that in severe fluorosis, there is a biological plausibility to this concept. However, this would not explain the findings reported here of a similar DMFS risk with moderate fluorosis, suggesting that at least part of the filled component may reflect cosmetic or misdiagnostic restorations.

Since fluorotic lesions could have been previously treated for reasons other than caries, a resulting overestimation of their past caries history could result if based on the DMFS index. DMFS comparisons between populations with different fluorosis levels in the moderate and severe categories thus need to be interpreted with caution in making inferences as to their relative caries experience, Given that the association between dental caries and fluorosis is uncertain at this point, further studies need to be conducted in a variety of populations using different study designs.

Conclusion

In the ecological study, no relationship between CFI and DMFS scores was found in 12-year-old children in non fluoridated Puerto Rico. However, at the individual level of analysis moderate and severe fluorosis may be associated with higher DMFS levels relative to children with lower NIDR/Dean's Index of fluorosis scores. Additional studies at the tooth level are needed to draw definitive conclusions. While controlling severe fluorosis is desirable, this will have little impact on overall high caries in Puerto Rican children. These findings suggest caution when interpreting caries experience using the DMFS index in populations with differing fluorosis levels.

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