Longitudinal Study of Non-cavitated Carious Lesion Progression in the Primary Dentition

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Abstract

Objectives: *This study reports changes in non-cavitated tooth surface diagnoses after a 4-year period.* ***Methods:*** *Dental examinations were conducted for Iowa Fluoride Study cohort children who had non-cavitated lesions in the primary dentition and were also examined an average of 4 years later in the mixed dentition. Comparison of fluoride exposures, socioeconomic factors, and beverage consumption patterns were made between children who had lesions progress and those who did not.* ***Results:*** *Of 129 non-cavitated pit and fissure lesions in the first exams, 40 (31%) progressed to either frank decay or filled status, while among 132 non-cavitated smooth surface lesions, 7 (5%) were filled and none had frank decay in the second exam. No fluoride, socioeconomic status or beverage variables were significantly associated with lesion progression.* ***Conclusions:*** *Non-cavitated smooth surface lesions rarely progressed in this age group, but nearly one-third of pit and fissure lesions progressed.*

Key Words: Dental caries, disease progression, primary dentition, children

Introduction

There has been a trend toward the use of more sensitive diagnostic criteria for caries (1-3), which record not only frank decay and filled lesions, but also non-cavitated lesions. The rationale for the use of more sensitive criteria are that a) non-cavitated, lesions can progress to cavitation (2), b) as caries prevalence decreases, it is becoming increasingly difficult to demonstrate differential effects in clinical trials (1) and c) the effectiveness of anticaries interventions can and should be evaluated by their impact on non-cavitated lesion progression (3).

While such a rationale appears logical and justified, there has been relatively little study of the incidence of non-cavitated carious lesions, and more importantly, little study of non-cavitated lesion progression, particularly in the primary dentition. In a study of 692 very young Swedish children, Grindefjord *et al.* (4) found that 64% of initial, non-cavitated lesions diagnosed at age 2.5 years progressed to frank decay by age 3.5 years, while an additional 8% became filled. A clinical trial of fluoride varnish evaluated the status of non-cavitated, active enamel lesions in 3- to -5-year-old children after nine months for both the treatment group (fluoride varnish) and a similar control group, and in the control group found that 25.4% of these lesions progressed to become frankly decayed or filled, with most progression on the occlusal surfaces (5). Only 10.6% progressed in the varnish group, again with most of the progressions occurring on the occlusal surfaces (5). A study that used radiographs to assess lesion progression on the proximal surfaces of the primary teeth, Vanderas, *et al.* (6) found that, among lesions confined to the outer half of enamel at baseline (age 6-8 years), 31% progressed after 12 months, and 60% progressed after 48 months. The study also considered the proximal surfaces of permanent first molars and found that only 2% of the lesions confined to the outer half of enamel progressed after 12 months, but that 59% did so after 48 months. Maupomé *et al.* (7) assessed caries progression over a 3-year period in permanent teeth of children in British Columbia, and found that progression occurred more frequently in subjects with pit and fissure lesions compared to smooth surface lesions, although analysis was not limited to progression of non-cavitated lesions, but rather considered progression to frank decay from sound, filled and non-cavitated lesions. This study found that residence in a non-fluoridated community, more frequent snacking and lower parental education levels were weakly associated with lesion progression. Clearly, there are very limited data available regarding the ability of non-cavitated lesions to progress to cavitated ones, particularly in the primary dentition. Thus, there is a need for more detailed study of non-cavitated lesions.

The purpose of this study was to track changes in non-cavitated (d_1) smooth surface and pit and fissure lesions in the primary dentition over an average of a 4-year time period among a cohort of children examined in the primary dentition (mean age = 5.2 years) and again in the mixed dentition (mean age = 9.2 years).

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Methods

Children were members of the Iowa Fluoride Study cohort, recruited at birth from March, 1992 to February, 1995(8, 9). All study procedures were approved by the Institutional Review Board under the auspices of the University of Iowa's Human Subjects Office. Parents of the participating children completed detailed questionnaires about family demographics at baseline, and about their children's fluoride exposures and diet at 3- to 6-month intervals (9). Questions posed to parents about their children included ones concerning dentifrice used, fluoride supplement use, use of fluoride mouth rinses and professionally applied fluorides. Individual questions about diet assessed fluoride intakes from dietary sources as well as specific types of food and beverages consumed over the most recent one-week period. Reliability and validity of the questions was assessed and reported previously (9). Fluoride exposure and dietary data were entered into a relational database and converted into SAS format. Cumulative estimates of fluoride intake and beverage consumption variables were generated using an area-under-the-curve (AUC) trapezoidal method.

Specifically, detailed questionnaire data concerning various aspects of dentifrice use and ingestion, dietary fluoride supplements, fluoride ingestion from water, other beverages and foods made with water were used to create separate variables, and these data were summed (to create a "total fluoride" variable) for each child at each questionnaire time period. Similarly, questionnaire data concerning dietary consumption of soda pop, powdered beverages (such as Kool-Aid® or Crystal Light®), juice and milk consumption were used to create separate variables for each questionnaire time point. A separate variable concerning frequency of tooth brushing was also created from a specific questionnaire item.

Dental examinations were conducted by two trained and calibrated examiners, with children examined in the primary dentition (n=698) and again in the mixed dentition (n=622) (J.W. & M.K.). The examiners were randomly assigned to participants at each examination, and each performed about half the examinations during both examination periods. Examinations were conducted using portable equipment and the teeth were briefly (< 5 seconds per tooth) dried with compressed air. A lighted dental mirror (DenLite®, Welch-Allyn Medical Products, Inc., Skaneateles Falls, NY) was used to improve visualization, as the examinations were primarily visual, although an explorer was used to confirm questionable findings. No radiographs were exposed for these examinations.

Criteria for assessing both smooth surface and pit & fissure non-cavitated (d_1/D_1) and cavitated ($d_{2\text{-}3}/D_{2\text{-}3}$) lesions were developed (8) based on the published literature (1,10,11) and used at both examinations, but did not differentiate between cavitated enamel and dentin lesions. Instead, lesions were categorized as cavitated ($d_{2\text{-}3}/D_{2\text{-}3}$) or non-cavitated ($d_1/D_1$) lesions. Specifically, smooth surface d_1 lesions were those that presented as distinct chalky white enamel, usually adjacent or close to the soft tissue margin with no clinically visible or irreversible loss of enamel structure or break in the enamel surface. In contrast, smooth surface $d_{2\text{-}3}$ lesions presented with demonstrable loss of enamel structure, often present with distinct chalky white enamel, and again usually adjacent or close to the soft tissue margin. For approximal smooth surfaces, $d_{2\text{-}3}$ lesions were scored only after confirmation using direct vision or transillumination, and/or after observing undermining with discoloration under the marginal ridge and either direct extension onto the proximal surface, or evidence of a break in the proximal enamel surface (8).

For pit and fissure surfaces, d_1 lesions often presented as distinct chalky white enamel directly adjacent to or into a pit or fissure which were typically stained light to dark brown. The d_1 lesion had to have no clinically visible or irreversible loss of enamel structure upon explorer probing in pits and fissures, and no resistance to removal of explorer during tactile examination with controlled modest pressure. In addition, no evidence of undermining could be present (8). The $d_{2\text{-}3}$ pit and fissure lesion could also have distinct chalky white enamel adjacent to a pit or fissure, but in contrast to d_1 lesions, there was demonstrable loss of enamel structure upon visual examination with evidence of active decay such as demineralization or undermining of enamel. Tactile examination revealing softness at the base of the lesion upon explorer probing with controlled modest pressure was also considered to be sufficient evidence, by itself, of a $d_{2\text{-}3}$ lesion (8).

Finally, lesions were scored as "arrested" when they appeared as shiny (not chalky) parchment white enamel, distinct from fluorosis on smooth surfaces. In the pit and fissure areas, a lesion was scored as arrested when it appeared darkly stained and shiny with no softness upon explorer probing, regardless of whether there was loss of tooth structure.

Examination data for both exams were entered into SPSS Data Entry 3.0™ and converted to SAS format for analysis. Inter-examiner reliability was reported previously for the primary dentition examinations (8), with percent agreements for d_1, $d_{2\text{-}3}$, and filled surfaces being 99% or greater. For the mixed dentition examinations, the percent agreement was 99% and the kappa value was 0.93 for $d_{2\text{-}3}f$ at the surface level, while for the d_1 surface level there was 98% agreement and kappa value was 0.51. To assess possible bias created by the different mix of examiners and participants for the two exams, mean differences in caries increments between all ordered pairwise combinations of examiners were computed. All such comparisons differed by 0.34 surfaces or less, and none of the differences were statistically significant at $p<0.05$. Children with d_1 lesions of the primary molars and canines (at the primary dentition exam) were identified, and the lesions were categorized as either pit & fissure or smooth surface and analyzed separately. For analysis, lesion progression was considered positive for surfaces that were either cavitated or filled at the mixed dentition exam. Analyses then focused on variables related to whether lesions progressed using a nested approach. Generalized linear models were used to assess relationships between non-cavitated lesion progressions and both demographic and exposure variables. All models were adjusted for correlation within participants and included time between examinations and initial $d_{2\text{-}3}$fs as covariates. Demographic variables included mothers' and fathers' educational levels, family income and child's sex. Demographic variables were assessed only at recruitment into the study. Specific exposure variables included area under the curve (AUC) estimates of brushing frequency per day from ages 5.5 to 8.5 years; AUC estimates of daily fluoride dentifrice use per day from ages 5.5 to 8.5; and AUC estimates of consumption of water, milk, 100% juice, powdered beverages, and regular soda pop from ages 5.5 to 8.5 years. The age 5.5 years to 8.5 years time period was chosen as the "best fit" for questionnaire data representing the actual period of time between examinations for most individuals.

Results

Children were examined in the primary dentition at a mean age of 5.2 years (range 3-7 years) and in the mixed dentition at a mean age of 9.2 years (range 7-12 years), so that the mean time between examinations was 4.0 years, with a range of 2.8 to 5.6 years. The amount of time between examinations did not differ significantly between those who had lesions progress and those who did not (p=0.96).

At the primary dentition exams, 153 children (21.9%) had one or more primary molar or canine surfaces with d_1 caries, with 182 pit and fissure and 219 smooth surfaces affected. Of these, 129 children (84%) who had 144 pit and fissure lesions and 179 smooth surface lesions at baseline were evaluated at follow-up exams. The number of lesions evaluated per child ranged from 1 to 12 for smooth surface lesions and 1 to 5 for pit and fissure lesions, with most participants with smooth surface lesions having four or fewer (84%), and most with pit and fissure lesions having either one (61%) or two (27%) lesions. As seen in Table 1, of the 144 non-cavitated pit & fissure lesions at the primary dentition exams 42 (29%) had progressed to be either filled (38) or have frank decay (4), whereas of the 179 non-cavitated smooth surface lesions at the primary dentition exams, only 6 (3%) lesions were filled and none exhibited frank decay at the mixed dentition exams. Using generalized logistic linear models with exchangeable correlation structure, the intracluster (within subject) correlation for lesion progression was 0.21 for smooth surfaces and 0.36 for pit and fissure surfaces.

As demonstrated in Table 2, participants with only smooth surface non-cavitated lesions at baseline had very little lesion progression (frank decay or filled) at follow-up compared to those who had only non-cavitated pit and fissure lesions. As presented in Table 2, among those indi-

TABLE 1
Summary of status of baseline d_1 lesions at follow-up examination

Surface Type	# lesions at baseline*	Follow-up: exfoliated†	filled	$d_{2\text{-}3}$	d_1	sealant	arrested	sound
Smooth Surface	179	39 (excl.)	6 (3%)	—	51 (28%)	—	5 (3%)	117 (65%)
Pit & Fissure	144	38 (excl)	38 (26%)	4 (3%)	16 (11%)	4 (3%)	12 (8%)	70 (49%)

*Number of lesions at baseline that were able to be evaluated at follow-up examination
† Exfoliated teeth were excluded from analyses

TABLE 2
Follow-up summary of participants with baseline d_1 lesions*

Participants with d1 lesions on:	N	Surface Type	Mean# lesions at baseline	Mean Percentage at Follow-up: filled	$d_{2\text{-}3}$	d_1	sealant	arrested	sound
Smooth Surfaces Only	37	Smooth Surface	2.9	0.3%	0%	24%	0%	4%	72%
Pit & Fissure Only	73	Pit & Fissure	1.5	28%	3%	12%	4%	8%	45%
Both Types of Surfaces	19	Smooth Surface	3.7	13%	0%	28%	0%	0%	59%
		Pit & Fissure	1.6	31%	7%	13%	0%	0%	49%

*Number of lesions at baseline that were able to be evaluated at follow-up examination viduals with both types of lesions at baseline, the proportions of both pit and fissure and smooth surface lesions progressing was greater than for individuals with either category alone.

Surface-level analyses of factors related to d_1 lesion progressions were conducted separately for smooth surface and pit and fissure lesions using generalized linear models, which adjusted for time between examinations and the number of frank decayed or filled surfaces at the first examination. For both smooth surface and pit and fissure lesions, no socioeconomic factors were significantly related to lesion progression among the factors tested (family income, mothers' or fathers' education, child's sex). For smooth surface lesions, no fluoride exposure or beverage consumption factors, nor tooth brushing frequency estimates, were significantly related to having lesion progression, although lower total fluoride exposure approached statistical significance ($p=0.07$). For pit and fissure lesions, less frequent tooth brushing and lower consumption of powdered beverages were significantly ($p=0.02$, and $p<0.01$, respectively) associated with caries progression.

Discussion

This study demonstrated that, while over 30% of pit and fissure non-cavitated (d_1) lesions progressed to frank decay or filled surfaces over an average four-year period, very few non-cavitated smooth surface lesions did so. Reasons for this are unclear, but it is likely that, as smooth surfaces are more accessible to oral hygiene, saliva, fluoride and other factors, they were less likely to progress. It is also possible that the criteria for pit and fissure d_1 lesions were more likely to include active lesions than were the criteria for smooth surface lesions, and that dentists were more likely to restore non-cavitated pit and fissure lesions than they were non-cavitated smooth surface lesions. Unfortunately, there is likely great variation in dentists' thresholds for restoring questionable lesions (14), which limits the interpretation of results because it is not clear whether lesions truly progressed over time, or whether a particular dentist merely restored a lesion that may or may not have progressed after the initial study examination.

As described previously, Grindefjord *et al.* (4) reported that over 70% of non-cavitated lesions in 2-year-olds progressed to cavitated or filled lesions during a one-year period, and using radiographic data, Vanderas *et al.* (6), reported that 60% of lesions progressed after four years. In contrast, when combining both pit and fissure and smooth surfaces in the present study, 15% (48/323) of lesions progressed. A difference in the age of the children compared to the Grindefjord *et al.* study may be the most likely explanation of the different results, as it is plausible that non-cavitated smooth surface lesions occur earlier in life (due to improper feeding habits) and progress earlier than do pit and fissure lesions. In other words, in the present study, most smooth surface lesion progression could have already occurred prior to the first examination at age 3-7 years, as evidenced by the finding that nearly half (44%) of $d_{2-3}f$ at baseline involved the smooth surfaces (8). As children were of similar age, the different results between the present study and that reported by Vanderas et. al., (6) is likely due to the clinical criteria used in the present study being quite different than radiographic criteria used in the Vanderas *et al.* study. That is, the radiographic criteria that initial lesions were those less than half way through the enamel were likely more indicative of active caries than were the visual-tactile criteria used in the present study. The classic radiographic study of caries lesion progression (12) suggests that early lesions in the primary dentition can progress through enamel in less than 24 months, consistent with those previously cited (4,6), so that the findings from the present study could reflect a lower-risk population.

The study results, however, are generally consistent with those reported by Autio-Gold and Courts (5), in that most lesion progressions or lesions that became filled occurred on pit and fissure surfaces. An additional similarity between these two studies is that a relatively high proportion of active enamel lesions became inactive. In the Autio-Gold and Courts study (5), 38% of lesions in the control group and 81% in the treatment group became inactive after 9 months, whereas in the present study 63% of baseline non-cavitated lesions were scored as either arrested or sound upon follow-up examination 4 years later.

The study findings that less frequent tooth brushing was associated with pit and fissure lesion progression are not surprising given that it is widely held that frequent tooth brushing, including brushing with fluoride dentifrice, prevents caries occurrence and progression. However, the finding that lower consumption of powdered beverages was associated with lesion progression is more puzzling, as previous research has suggested powdered beverages were associated with caries occurrence (13). The questionnaire data did not specifically distinguish between sugar-added and sugar-free powdered beverages, so that while some beverages in this category (e.g., Kool-Aid®) have added sugar, others are sugar free (e.g., Crystal Light®).

While the longitudinal study design and community-based sample are strengths of this study, there were limitations. First, the caries criteria used were based completely on field clinical examination without radiographs, so that, as discussed previously, the study results may not be comparable to those obtained from studies that assessed lesion progression radiographically. Second, the sample was small and had limited statistical power to detect differences, so that some relationships between lesion progression and the independent variables may have been missed. Lastly, the sample was not representative of any defined population and due to the longitudinal nature of the study, was skewed toward higher socioeconomic groups. Thus, some caution is warranted in applying results to other populations.

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