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ORIGINAL ARTICLE

The relationship of enamel defects and caries: a cohort study

AGR Targino[1], A Rosenblatt[2], AF Oliveira[3], AMB Chaves[3], VE Santos[2]

[1]*Department of Clinical and Social Dentistry, Federal University of Paraiba, João Pessoa, Brazil;* [2]*Pediatric Dentistry, Faculty of Dentistry of Pernambuco, Camaragibe, Brazil;* [3]*Morphology Department, Federal University of Paraiba, João Pessoa, Brazil*

OBJECTIVE: Is there a relationship between enamel defects and early childhood caries?
METHODS: A total of 275 children participated in a cohort study from birth to 54 months of age. Enamel defects were determined by the development defects enamel index and dental caries was registered according to the WHO criteria. Data were analyzed using descriptive, analytical techniques, multivariate analysis, and evidence-based tools as number needed to harm (NNH).
RESULTS: In the follow up, 224 children were still in the study, 81.3% presented at least one tooth with enamel defect and 44.2% had dental caries. An association was found between enamel defects and dental caries ($P = 0.0091$). Multivariate analysis showed that night bottle-feeding, absence of fluoride and enamel defects were predictors of dental caries at 18 months ($P < 0.05$). Enamel defect was the only statistically significant variable to influence the development of caries at 24, 30, 36, and 42 months. At 48 months, the use of fluoride toothpaste had effect on the decrease of caries ($P < 0.05$). The NNH for enamel defects in relation to dental caries was 3.0, at 24 months and 5.0 at 54 months.
CONCLUSION: Enamel defect is a predisposing factor for ECC.
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Keywords: early childhood caries; enamel defects; enamel hypoplesia; caries; deciduous teeth

Introduction

Early childhood caries (ECC) is a severe health condition found mostly in children living in socially disadvantaged communities in which malnutrition is a social and health disparity (De Grauwe *et al*, 2004; Feldens *et al*, 2010).

Based on the available evidence, the etiologic factors related to ECC are high sugar intake (Rosenblatt and Zarzar, 2002; Harris *et al*, 2004; Milgrom *et al*, 2000; Seow *et al*, 2009; Thitasomakul *et al*, 2009; Uribe, 2009; Warren *et al*, 2009; Feldens *et al*, 2010); lack of oral hygiene (Seow *et al*, 1996; Harris *et al*, 2004; Uribe, 2009; Warren *et al*, 2009); lack of fluoride exposure (Seow *et al*, 1996; Peres *et al*, 2003; Leake *et al*, 2008); and enamel defects (Kanchanakamol *et al*, 1996; Seow *et al*, 1996; Ribeiro *et al*, 2005; Oliveira *et al*, 2006; Milgrom *et al*, 2000; Seow *et al*, 2009; Uribe, 2009).

Enamel defects are visible deviations from the normal translucent appearance of the tooth enamel resulting from early damage to the enamel organ (Suckling, 1989; FDI Commission on Oral Health, Research and Epidemiology, 1992). It is difficult to express the precise etiology of such defects because of its non-specific appearance and also to the limited data available on the chronology of the development of the human dentition (Seow, 1997). Some authors report that those defects are related to malnutrition and early childhood infections (Lai *et al*, 1997; Agarwal *et al*, 2003; Crombie *et al*, 2009).

Teeth showing enamel hypoplasia present irregular and retentive surfaces leading to increased risk for the adhesion and colonization of bacteria; therefore, infants presenting enamel hypoplasia have increased levels of *Streptococcus mutans* (Li *et al*, 1994; Uribe, 2009; Seow *et al*, 2009), and higher risk for dental caries (Pascoe and Seow, 1994; Lai *et al*, 1997; Seow *et al*, 2009; Uribe, 2009).

The current literature includes a vast number of cross-sectional studies reporting on the association between enamel defects and dental caries (Li *et al*, 1994; Pascoe and Seow, 1994; Kanchanakamol *et al*, 1996; Seow, 1997; Milgrom *et al*, 2000), however, longitudinal study represent the best study design to investigate the cause and effect relationship.

The purpose of this study was to assess the relationship between enamel defects and the development of

Correspondence: Aronita Rosenblatt, Av. Boa Viagem 560 ap 06, Boa Viagem Recife, Pernambuco CEP 51011-000, Brazil. Tel: 55 81 318 33756, Fax: 55 81 318 33758, E-mail: rosen@nlink.com.br
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dental caries in a cohort of children followed up for 54 months. This study also looks if there is any association of tooth brushing, diet and the use of fluoride toothpaste with the development of ECC.

Materials and methods

Subjects

The children were recruited at birth at a public maternity hospital in João Pessoa, a facility that provides Gynecologic and Obstetric care for poor families. This city is the capital of the state of Paraiba located in the northeastern part of Brazil, which has the lowest per capita income in the country. About 39% of the families survive with the half of the minimum legal wage and from a total of 597 934 inhabitants living in the city, only 148 000 have access to piped water, which fluoride content is lower than 0.2 ppm (IBGE, 2000). After recruitment, the children had their first dental examination at the age of 6 months, at their homes, in the suburban areas of extreme poverty.

The children were born in January/February 2000. Oliveira *et al* (2006) reported on the 24 months follow up, whereas Chaves *et al* (2007) reported on the 36 months follow up. Our study is based on the same population described by the two previous authors, however, at 12–54 months follow up.

The calculation of the sample size was based on a study by Li *et al* (1996)as described by Oliveira *et al* (2006). After 54 months, the dropout rate was 18%; however, a total of 224 children still remained in the trial, a sample large enough to provide statistically significant results.

Data collection

Ethical clearance was obtained from the Maternity Hospital Human Research Ethics Committee and the informed consent was obtained from parents at the time of birth.

The subjects were examined every 6 months from 12 to 54 months of age by three calibrated investigators. The first investigator examined children from 12 to 18 months of age, the second examiner, from 24 to 36 months and the third, from 42 to 54 months. Parents were interviewed at the same occasion.

The interviews took place prior to each dental examination and the questionnaire has been reported by Oliveira *et al* (2006) and Chaves *et al* (2007).

The children had their teeth visually examined at home, under natural light, with a dental mirror and a blunt probe, in the knee–knee position. The teeth were cleaned with gauze and examined for enamel defects using the development defects enamel (DDE) index proposed by the Fédération Dentaire Internationale (1992) and recorded on a comprehensive chart according to Oliveira *et al* (2006). We examined the buccal and lingual surfaces of each anterior tooth and the buccal, the lingual, and the occlusal surfaces of the posterior teeth. The enamel defects were classified according to their position on the crown, as gingival, incisal or occlusal half, pit and fissure and cusp. Defects measured <1 mm in diameter were excluded from the sample and any existing doubt concerning the presence of a defect was scored as normal.

Caries was evaluated following the World Health Organization (WHO) standard criteria for dental caries diagnosis (WHO, 1997) and if any tooth surface had a detectable softened area, the lesion was diagnosed as carious. Children were classified as presenting severe early childhood caries (ECC-S) when dental caries was present on any smooth surface, as reported by Drury *et al* (1999). However, white-spot lesions were not scored as carious lesions; they were differentiated from enamel opacities when placed adjacent to the gingival margin and extend along the buccal or lingual surfaces, while enamel opacities had no specific location on the tooth surface (Seow, 1997). The partially erupted teeth were not recorded, except when defects or caries were present on the erupted portion of the crown.

As there is a lack of access to health care for poor people living in this urban area, the children enrolled in this study were referred for treatment to the community dental clinics, to the University Dental Clinic and emergencies were treated free of charge by the dental examiners in their private dental clinic.

Calibration and reproducibility

Consistency in diagnosis among examiners was checked by inter- and intra-examiner variability tests. For the first examiner, calibration for enamel defect was conducted in a pilot study (Oliveira and Rosenblatt, 2004) when enamel defects were photographed and recorded. For the second and the third examiners, the calibration for enamel defects followed the same procedures of the pilot study. Each examiner examined the photographs twice on separate occasions, 24 h apart. Furthermore, to guarantee consistency of diagnosis for dental caries and enamel defects, the second examiner also took part in the 18-month examination, as well as the third examiner took part in the 36-month examination.

To evaluate inter-examiner agreement, 10% of the sample was randomly selected to be examined by both examiners on separate occasions, throughout the 5-year trial.

Data analysis

We used the SAS and SPSS 11.0 statistical software packages for the data analysis and both descriptive and analytical analyses were performed. We also used the chi-squared, Fischer's Exact test and the Pearson's test for categorical independent variables – enamel defects, daily tooth brushing frequency, exposure to fluoride toothpaste, sugar intake, breast-feeding, night breast-feeding, bottle-feeding, night bottle-feeding and sugar in the baby bottle (dependent variable – Table 1). P value <0.05 was considered statistically significant. A 95% confidence interval was used for comparisons of different results within subgroups.

The cumulative incidence was calculated by the number of new cases during a period divided by the number of subjects at risk in the population at the beginning of the study.

Table 1 List of dependent and independent variables

Dependent variable	*Category*	*Variable definition*	*Logistic regression*
Early childhood caries	Absent/present	Present when the child had ECC or ECC-S	Included
Independent variables	Categories	Variable definition	Logistic regression
Enamel defects	Absent/present	Present in one or more teeth	Included
Daily brushing habits	No/Yes	Present when helped by the parents at least once a day.	Included
Fluoride exposure	No/yes	Present when fluoride toothpaste was used at least once a day	Included
Dietary habits	Non-cariogenic/ cariogenic	A cariogenic diet was present when there were sugary snacks between meals	Excluded
Night breast-feeding	No/yes	Present when offered at least once per night	Included
Night bottle-feeding	No/yes	Present when used at least once per night	Included
Sugar in the baby bottle	No/yes	Present when the there was sugar added to the drink.	Included

ECC, early childhood caries; ECC-S, severe early childhood caries.

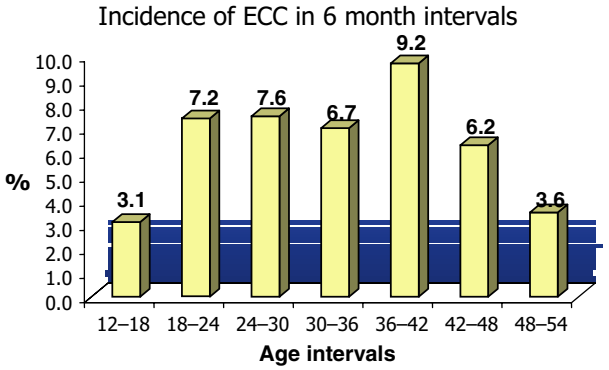
Logistic regression analysis was also carried out using the SPSS software to assess the importance of the co-variables in the model. The statistical significant variables ($P < 0.20$) for the model were selected by bivariate analysis. The variables were combined as shown in Table 1. Six logistic regression models were developed to predict caries experience at 54 months, including all the representative variables ($P < 0.20$) at 18, 24, 30, 36, 42, and 48 months of age. Stepwise elimination was used to reduce the number of variables in the models. The final model included the variables that were significant at $P < 0.05$. The lack of a model, including the representative variables at 12 months, is explained by the fact that 25 children did not show any erupted teeth at this age, yet. The Centre for Evidence-Based Medicine (Toronto; http://www.cebm.utoronto.ca/practise/ca/statscal/) calculator was used for calculating the **NNH**, which is an epidemiological measure that indicates how many patients need to be exposed to a risk-factor over a specific period to cause harm in one patient that would not otherwise have been harmed. Intuitively, the lower the number needed to harm (NNH), the worse the risk-factor.

Results

Inter- and Intra-examiner agreement for DDE and Caries scoring

Cohen's Kappa values for enamel defects for the inter-examiner agreement were 0.89 for the examinations carried out between 18 and 24 months and 0.78 for those carried out between 36 and 42 months. However, the levels of agreement for dental caries during the same period were 0.94 and 0.83, respectively.

The Cohen's Kappa values (intra-examiner agreement) varied from 0.90 to 0.98 for enamel defects and from 0.94 to 0.98 for dental caries between 12 and 18 months. At 24- to 36-month interval, Cohen's kappa value for enamel defects varied from 0.94 to 0.98 and for dental caries, from 0.96 to 0.98. In relation to the third examiner, Cohen's Kappa value for enamel defects varied from 0.96 to 0.90 and for dental caries, from 0.94 to 0.90.



Graph 1 Incidence of ECC in six-month intervals

Association of dental caries with enamel defects

We examined a total of 224 children from the age of 12 to 54 months. At 12 months, none of the infants presented dental caries. There were 9.2% of children presenting carious teeth at 42 months and there was a decrease from 6.2% to 3.6% between 48 and 54 months, although there was an increase on active caries (Graph 1).

The present results suggested that at 54 months, 48.4% of the children presenting caries also had enamel defects ($P = 0.0091$). The risk of the children presenting enamel defects to develop dental caries was approximately two times greater than that of those without defective teeth. The NNH ranged from 3.0 at 24 months, to 5.0 at 54 months (Table 2). The incidence of dental caries in the exposed group compared with the group without enamel defects was greater along the cohort study. The cumulative incidence of caries was 0.54 from 18 to 54 months.

Twenty five children were excluded for the statistical analysis given that they had no erupted teeth until the child was 12 months of age.

Table 3 shows the relationship between different types of enamel defects and dental caries. The enamel hypoplasia was the most frequent type of enamel defect associated with dental caries. From the 10.6% of the

Table 2 Cumulative incidence of enamel defects and dental caries from 12 to 54 months of age

Age (months)	*Enamel defects*	*Dental Caries*				*TOTAL*			
		Present		*Absent*					
		n	*%*	n	*%*	n	*%*	P-*Value*	*RR (95.0% CL)*
12	Present	–	–	67	100.0	67	100.0	ND	ND
	Absent	–	–	132	100.0	132	100.0		
Total		–	–	199	100.0	199	100.0		
18	Present	6	4.4	131	95.6	137	100.0	$P^a = 0.2546$	3.74 (0.46 a 30.53)
	Absent	1	1.2	86	98.8	87	100.0		1.00
									NNH = 17.0 (9–167)
Total		7	3.1	217	96.9	224	100.0		
24	Present	23	14.0	141	86.0	164	100.0	$P^b = 0.0022$	ND
	Absent	–	–	60	100.0	60	100.0		1.00
									NNH = 3.0(3–5)
Total		23	10.3	201	89.7	224	100.0		
30	Present	39	22.5	134	77.5	173	100.0	$P^b = 0.0007$	ND
	Absent	1	2.0	50	98.0	51	100.0		1.00
									NNH = 5.0
Total		40	17.9	184	82.1	224	100.0		
36	Present	54	30.5	123	69.5	177	100.0	$P^b < 0.0001$	ND
	Absent	1	2.1	46	97.9	47	100.0		1.00
									NNH = 5.0
Total		55	24.6	169	75.4	224	100.0		
42	Present	74	41.3	105	58.7	179	100.0	$P^b < 0.0001$	6.20 (2.05 a 18.76)
	Absent	3	6.7	42	93.3	45	100.0		1.00
									NNH = 3.0
Total		77	34.4	147	65.6	224	100.0		
48	Present	83	45.9	98	54.1	181	100.0	$P^b = 0.0011$	2.46 (1.29 a 4.70)
	Absent	8	18.6	35	81.4	43	100.0		1.00
									NNH = 4.0
Total		91	40.6	133	59.4	224	100.0		
54	Present	88	48.4	94	51.6	182	100.0	$P^b = 0.0091$	1.85 (1.09 a 3.13)
	Absent	11	26.2	31	73.8	42	100.0		1.00
									NNH = 5.0
Total		99	44.2	125	55.8	224	100.0		

ND – *P* value or RR not determined.
[a] – Fischer's Exact chi-squared test.
[b] – Pearson's chi-squared test.
CL, confidence limits; NNH, number needed to harm.

teeth with dental caries, only 4.4% where present on teeth without enamel defects, which indicate the influence of enamel defects on the development of dental caries.

Factors influencing dental caries using a logistic regression model

Some etiologic factors are known as risk factors associated with the development of ECC. A multivariate analysis using a regression model was conducted to test the hypothesis that enamel defects are related to the development of ECC.

Two statistical models were used. At 18 months, night bottle-feeding, no fluoride exposure and enamel defects were among the selected variables that showed statistical significance ($P \leq 0.05$). At 24, 30, 36, and 42 months, enamel defects were the only variable proved to be statistically significant for the development of caries. At 48 months, the lack of exposure to fluoride toothpaste and enamel defects was the variables that showed the strongest relationship to the development of caries at 54 months (Table 4).

Discussion

The results of this longitudinal study show that ECC in preschoolers has a strong relationship to enamel defects, when compared with children who did not present those defects at that same age interval. Such association has been previously reported by Oliveira *et al* (2006) which is in agreement with other cross-sectional studies (Li *et al*, 1994; Pascoe and Seow, 1994; Kanchanakamol *et al*, 1996; Seow *et al*, 1996; Milgrom *et al*, 2000) and case–control study (Uribe, 2009). However, a longitudinal study may represent the best study design to check the influence of certain variables before the disease occurs, given that in cross-sectional studies untreated caries lesions may mask enamel defects.

As dental caries do occur in enamel hypoplasia sites, the first may mask these preexisting enamel defects, a fact already mentioned in previous cross-sectional studies (Johnsen, 1982). Likewise, when reporting on the occurrence of enamel hypoplasia and dental caries in 3–4 year olds, Vignarajah and Williams (1992)

Table 3 Relationship among different types of enamel defects and dental caries at 54 months of age

	Dental caries						
	Present		*Absent*		*Total*		
Enamel defects	n	*%*	n	*%*	N	*%*	P-*value*
Absent	146	4.4	3191	95.6	3337	100.0	< 0.0001*
Demarcated opacity	4	3.0	130	97.0	134	100.0	
Diffuse opacity	58	12.6	401	87.4	459	100.0	
Hypoplasia (reduced thickness)	5	3.8	125	96.2	130	100.0	
Hypoplasia(missing enamel)	181	65.3	96	34.7	277	100.0	
Opacity + hypoplasia	81	56.6	62	43.4	143	100.0	
Total	475	10.6	4005	89.4	4480	100.0	

**P*-values obtained by Pearson's chi-squared test.

Table 4 Regression analysis model for dental caries at 54 months

	*Model 1**		*Model 2***	
Variables	*OR (95% CL)*	P	*OR (95% CL)*	P
18 months				
Night bottle-feeding	0.47 (0.3–0.8)	0.007	0.49 (0.3–0.9)	0.021***
No fluoride exposure	1.76 (1–3)	0.039	2.16 (1.2–3.9)	0.010***
Enamel defects	4.02 (2.21–7.30)	< 0.0001	4.10 (2.21–7.60)	< 0.001***
Lack of daily brushing habits	1.75 (1–3)	0.038		
Sugar in the bottle	0.47 (0.3–0.9)	0.017		
24 months				
Night breast-feeding	1.89 (1–3.7)	0.060	1.84 (0.9–3.7)	0.79
Enamel defects	2.82 (1.5–5.4)	0.001	2.79 (1.5–5.4)	0.002***
Sugar in the baby bottle	0.63 (0.3–1.2)	0.16		
30 months				
Enamel defects	2.89 (1.4–5.8)	0.002	2.88 (1.4–5.8)	0.003***
Sugar in the bottle	0.60 (0.3–1.1)	0.092	0.61 (0.3–1.1)	0.103
36 months				
Enamel defects	2.81 (1.4–5.8)	0.003	2.74 (1.3–5.7)	0.006***
No fluoride exposure	1.89 (0.7–5.2)	0.20	1.88 (0.7–5.2)	0.226
Sugar in the bottle	0.68 (0.4–1.2)	0.17	0.66 (0.4–1.2)	0.16
42 months				
Cariogenic habits	0.30 (0.1–16)	0.14	0.26 (0.1–1.4)	0.122
Enamel defects	2.99 (1.4–6.3)	0.002	3.12 (1.5–6.6)	0.003***
48 months				
No fluoride exposure	2.14 (1.1–4.1)	0.016	2.23 (1.2–4.3)	0.015***
Enamel defects	2.75 (1.3–5.8)	0.006	2.85 (1.3–6.1)	0.007***
Daily brushing habits	1.42 (1.1–1.9)	0.018		

*Model 1 – Variables included in the model after bivariate analysis $P \leq 0.20$.
**Model 2 – Variables that maintained $P \leq 0.20$ and submitted to logistic regression.
***Significant association ($P < 0.05$) after logistic regression.
OR, odds ratios; CL, confidence limits.

observed that enamel opacity occurred mostly on the gingival site.

Given that the gingival site which is also the enamel layer first to be attacked is located on the buccal surface of the tooth, we assume that it is caused by calcification damages occurring in the final phase of mineralization. This was previously mentioned by Matee *et al* (1994) and Lai *et al* (1997);however, in Lai's study, the first examinations were carried out at 30 months of age, when some defects had already been misdiagnosed as dental caries.

A logistic regression analysis was conducted to evaluate the correlation of ECC with their risk factors at 54 months of age. The association between enamel defects and caries was observed in the two logistic regression models. This cohort study support the hypothesis that enamel defects predispose children to an increased caries risk as reported by other studies (Li *et al*, 1996; Lai *et al*, 1997; Oliveira *et al*, 2006; Chaves *et al*, 2007; Milgrom *et al*, 2000; Uribe, 2009). Other risk factors for dental caries were selected by the model, but they were not statistically associated with dental caries. This indicates a great influence of enamel defects on dental caries, especially in children living in socially disadvantaged communities as reported by Oliveira *et al* (2006).

The risk of children presenting enamel defects to develop dental caries was approximately two times

greater than those without these defective teeth. This risk varied along the study and at 24 months, NNH was 3.0. According to Oliveira *et al* (2006), children presenting enamel defects were 15 times more likely to develop dental caries than children showing no defects.

Among the types of defects found in this sample, enamel hypoplasia was found to be most frequently associated with dental caries, as described in previous studies (Matee *et al*, 1994; Kanchanakamol *et al*, 1996; Li *et al*, 1996; Milgrom *et al*, 2000).

The regression analysis models show that the following variables also influenced the development of dental caries at 54 months: the lack of use of fluoridated toothpaste at 18 and 48 months and the use of night feeding-bottle at 18 months. Twetman (2008, 2000), in two literature reviews on prevention of ECC, reported fluoride toothpaste as the most cost-effective home-care caries preventive treatment and Milgrom *et al* (2000) in a cohort of children aged from 6 to 36 months using semi-annual fluoride varnish applications indicated that it is the best professional method and found no association between dental caries and the use of night feeding-bottle.

In general, socioeconomic status has been considered as an indicator for caries risk assessment (Feldens *et al*, 2010; Agarwal *et al*, 2003; Oliveira *et al*, 2006; Li *et al*, 1996; Disney *et al*, 1992; Peres *et al*, 2005; Oliveira *et al*, 2008). The present results bring up the discussion on ECC prevention, which should imply on a holistic approach to health. Malnutrition plays an important role in dental development (Feldens *et al*, 2010; Li *et al*, 1996; Chaves *et al*, 2007; Peres *et al*, 2005; Oliveira *et al*, 2008; Ngoenwiwatkul and Leela-adisorn, 2009; Psoter *et al*, 2005) and the lack of basic nutrients in the intrauterine phase could be a strong determinant for ECC (Uribe, 2009). The cumulative incidence of 0.54 indicates that it is high among the target population which suggests that there is a lack of social and health promotion policies for this target population. Therefore, the authors suggest that public policies should focus on the improvement of the quality of life and the general health of the less favored social groups.

Conclusion

There was a strong relationship between ECC and enamel defects in children aged from 18 to 54 months. The use of fluoridated toothpaste was found to be related to the decrease in the development of dental caries.

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