

## ORIGINAL REPORT: EPIDEMIOLOGIC RESEARCH

# Caesarean Section Does Not Increase the Risk of Caries in Swedish Children

E. Brandquist<sup>1,2</sup>, G. Dahllöf<sup>1</sup>, A. Hjern<sup>3</sup>, and A. Julihn<sup>1,2</sup>

**Abstract:** *Caesarean section has been shown to affect the health of the child. Only a few studies have investigated whether the mode of delivery is associated with dental caries, and they present conflicting results. Our study investigated whether dental caries was associated with delivery method in Swedish preschool children. This retrospective register-based cohort study included all children born from 2000 to 2003 who were residing in Stockholm County, Sweden, at 3 y of age (n = 83,147). The study followed the cohort until individuals were 7 y of age. Children examined at 3 and 7 y constituted the final study cohort (n = 65,259). We dichotomized the key exposure “delivery starts by caesarean section” and analyzed it in univariate analyses as well as in multivariate analyses. The multivariate analyses used 3 outcomes: caries experience at age 3 (deft >0 [decayed, extracted, and filled teeth]), caries increment between 3 and 7 y of age ( $\Delta$ deft > 0), and caries experience at age 7 (deft > 0). Of the final cohort, 15% (n = 9,587) were delivered by caesarean section. At 3 y of age, the results showed no*

*statistically significant association between caesarean section and caries experience (odds ratio = 0.92, 95% confidence interval [CI] = 0.82 to 1.04). Between 3 and 7 y of age, the association of caesarean section on caries increment was 0.88 (95% CI = 0.83 to 0.94) and at 7 y of age, 0.88 (caries experience; 95% CI = 0.82 to 0.94). Higher mean values for caries experience and caries increment were observed in vaginally delivered children. We found that preschool children who were delivered by caesarean section do not represent a group with an excess risk of developing dental caries. Furthermore, the statistically significant associations with caries increment and caries experience at age 7 were negative.*

### Knowledge Transfer Statement:

*Children born by caesarean section are at greater risk of developing asthma and obesity. The proportion of elective caesarean sections without a medical indication has increased over the years; therefore, it is important to know how this mode of delivery affects oral health of the child. The results*

*show that children who are delivered by caesarean section are not at greater risk of developing dental caries, and clinicians can use these findings in their risk assessment.*

**Keywords:** dental caries, longitudinal study, mode of delivery, preschool children, register-based study, risk factor

### Introduction

Of the 110,000 children delivered in Sweden every year, about 17% are delivered by caesarean section (Gottvall et al. 2014). The mode of delivery has been shown to affect the health of the child in many aspects, both short term and long term. Caesarean section delivery has been associated with initial breast-feeding problems and delayed onset of lactation (Wallby and Hjern 2009). Over the long term, children born by caesarean section are at greater risk of developing asthma (Thavagnanam et al. 2008; Tollanes et al. 2008) and childhood obesity (Kuhle et al. 2015).

Several studies have also shown that the method of delivery affects the gut microbiota of newborn children

DOI: 10.1177/2380084417716073. <sup>1</sup>Division of Pediatric Dentistry, Department of Dental Medicine, Karolinska Institutet, Stockholm, Sweden; <sup>2</sup>Pediatric Dental Clinic in Gothenburg, Public Dental Service in Västra Götaland, Sweden; <sup>3</sup>Clinical Epidemiology, Department of Medicine, Karolinska Institutet and Centre for Health Equity Studies, Stockholm, Sweden. Corresponding author: A. Julihn, Pediatric Dental Clinic in Gothenburg, Public Dental Service in Västra Götaland, POB 7163, SE-402 33 Gothenburg, Sweden. Email: annika.julihn@vgregion.se



(Hyde et al. 2012). The establishment of the microflora in the gut depends on a complex interplay of external and internal factors, as well as the mode of delivery, feeding practice, mother's microflora, and host factors. Greater microbial diversity associates with good health, not only in the gut, but also in the oral cavity (Lif Holgerson et al. 2011). Thus, some have speculated that children delivered by caesarean section will have an increased risk of dental caries when compared with children delivered vaginally. Since oral mutans streptococci have been found at a younger age in children born by caesarean section than in children delivered vaginally (Li et al. 2005). Furthermore, children delivered vaginally are reported to have an oral microflora with a higher prevalence of certain strains of health-related oral streptococci and lactobacilli (Nelun Barfod et al. 2011). In contrast, Pattanaporn and colleagues (2013) found that children delivered vaginally had higher levels of caries-associated mutans streptococci than children born by caesarean section.

Only a few studies have investigated whether the delivery method is associated with dental caries, and they present conflicting results (Peretz and Kafka 1997; Fontana et al. 2011; Nelun Barfod et al. 2012; Pattanaporn et al. 2013). Since the proportion of elective caesarean sections without a medical indication has increased over the years, it is important to know whether this choice affects the oral health of the child in the long term. Thus, the aim of this study was to investigate whether delivery mode was associated with dental caries development in preschool-age children. We hypothesized that children delivered by caesarean sections would have an increased risk of developing dental caries compared with vaginally delivered children.

## Materials and Methods

### Study Design

The present retrospective cohort study is based on information collected from data sources at the Public Health Care

Administration in Stockholm, as well as from the national registers at the National Board of Health and Welfare and Statistics Sweden. The Regional Ethical Board in Stockholm and the Swedish Data Inspection Board, a national agency that serves as an institutional review board for studies using database linkage, approved the protocol for this study.

### Subjects

The study included all children born from 2000 to 2003 who resided in Stockholm county, Sweden, at 3 y of age ( $n = 83,147$ ). We followed this cohort until the individuals reached 7 y of age. During this period, the subjects received regular dental checkups at the Public Dental Service, with private practitioners, or at the Division of Pediatric Dentistry, Department of Dental Medicine, at Karolinska Institutet. A total of 65,259 children (33,423 boys and 31,836 girls) were examined at 3 and 7 y of age and thus constituted the final study cohort. The dropout rate was 22%, and the most common reason for dropping out was that the child had moved out of the area.

### Data Collection Concerning Dental Caries

Data on manifest caries lesions were collected from clinical and radiographic examinations in children in Stockholm. The registration sheets for the 3- and 7-y-old children comprised the following caries index: dt = decayed teeth, et = extracted teeth, and ft = filled teeth. The process defined manifest caries as caries on smooth surfaces at the lowest level that can be verified as a cavity and detectable by probing or, in fissures, by a catch of the probe under slight pressure. It defined proximal caries on radiographs as manifest caries in which the lesion clearly extends into the dentin (Koch 1967). Not all children received radiographic examination at a specific age, only those for whom it was indicated.

The decayed, extracted, and filled primary teeth (def<sup>t</sup>) index measured the severity of the caries experience in children at 3 and 7 y of age. The caries

increment comprised all new caries lesions in primary teeth that developed between 3 and 7 y of age (i.e., the difference between the def<sup>t</sup> values at 3 and 7 y). No permanent teeth were included in the age 7 outcomes.

### Population-Based Registers

In Sweden, the usefulness of the registers in epidemiologic research is facilitated by the personal identity number, which is a 10-digit number unique to each resident and recorded in all health and census registers (Ludvigsson et al. 2009). The personal identity number makes it possible to track each individual through the various registries. The present study used information from the Medical Birth Register (MBR), the Total Population Register, the Income and Taxation Register, and the Register of Education.

### Medical Birth Register

The Centre for Epidemiology at the Swedish National Board of Health and Welfare maintains the Swedish MBR. We collected the following variables from the MBR: sex, gestational weeks, method of delivery, birth weight, Apgar score at 5 min, parity, maternal age, maternal smoking habits during early pregnancy, and the mother's height and weight at the first visit to the public maternity health care clinic. The body mass index (BMI) of the mother was calculated and classified as <25 or ≥25. We chose "delivery starts by caesarean section" as our key exposure. The variable means that the childbirth starts with caesarean section before labor contractions have started, and it includes elective and emergency caesarean sections. If mothers labored for a time and then a caesarean section was done because of lack of progress, they were excluded from the study ( $n = 1,547$ ). The variable was initially divided into 2 subgroups: elective ( $n = 4,303$ ) and emergency caesarean section ( $n = 5,284$ ). These subgroups were subsequently merged into 1 group since the primary results exhibited small differences between the 2 subgroups.

### Total Population Register

Statistics Sweden maintains the Total Population Register. From this register, we collected information on the mother's country of birth and analyzed it in statistical analyses as "mother born in Sweden" or "mother born abroad."

### Income and Taxation Register

The Swedish National Tax Board collects data on individuals' annual income tax based on income tax returns and tax-authority decisions. The board then sends summary statistics to Statistics Sweden. From this register, we collected information regarding the family's income from the 2004 survey. We categorized and analyzed the variable "family income" into quintiles from highest income to lowest income in the statistical analysis.

### Register of Education

We obtained data on maternal education level from the Register of Education, which is updated each year in April. In the statistical analysis, we classified the variable "education level" according to the number of years of schooling in 2004: low ( $\leq 9$  y), intermediate (10 to 12 y), and high ( $> 12$  y).

### Statistical Analysis

All data management and statistical analyses were based on SPSS 22.0 (IBM Corp.). Data analysis employed frequency tables, cross tables, the Mann-Whitney *U* test, the Pearson chi-square test, and logistic regression, estimating associations with the odds ratio (OR) and a 95% confidence interval (CI). We considered all *P* values  $< 0.05$  to be significant, based on 2-tailed tests.

We dichotomized the key exposure "delivery starts by caesarean section" and analyzed it in a univariate analysis as well as in multivariate analyses. The multivariate analyses used 3 outcomes: caries experience at age 3 (deft), caries increment between 3 and 7 y of age ( $\Delta$ deft), and caries experience at age 7 (deft). The analyses dichotomized all

outcomes to distinguish subjects with (deft  $> 0$ ) and without (deft = 0) caries experience, as well as subjects with ( $\Delta$ deft  $> 0$ ) and without ( $\Delta$ deft = 0) caries increment.

To analyze "delivery starts by caesarean section" as a potential risk factor for caries development at preschool age, we adjusted the variable for potential confounders. Selection of the confounders included in the models used a combination of methods, with confounders selected according to their association with the outcome, as well as their association with the exposure and their subsequent influence on the outcome. Possible confounders were entered into the model in different groups, and adjusted multiple logistic regression analyses were performed for each group of variables to determine whether the variable was associated with the outcome. In model 1, no adjustments were made. In model 2, adjustments were made for sex and maternal age. In model 3, adjustments were made for gestational age, birth weight, Apgar score, and parity. For model 4, adjustments were made for maternal country of birth, maternal educational level, maternal BMI, maternal smoking in early pregnancy, and family income. Finally, in model 5, all groups of variables were included.

To control for confounding, additional multivariate logistic regression analyses were performed concerning the outcomes caries experience at 7 y of age and caries increment, since these outcomes were statistically significant. This logistic regression analysis began with a full model including all variables in the univariate logistic regression analysis. The model was then reduced by removing insignificant variables one by one until only significant covariates remained.

### Results

Of the final cohort ( $n = 65,259$ ), 15% ( $n = 9,587$ ) were delivered via caesarean section; 70% ( $n = 45,505$ ) were delivered vaginally; 2% ( $n = 1,547$ ) were excluded; and 13% ( $n = 8,620$ ) were missing data. Table 1 shows caries experience at 3 y

of age, total caries increment between 3 and 7 y of age, and caries experience at 7 y of age in relation to delivery method. There were statistically significant differences between children born by vaginal delivery and children born by caesarean in all analyses, with higher mean values for caries experience and increment in vaginally delivered children.

### Child Characteristics and Sociodemographic Background

Table 2 contains a summary of the child characteristics and sociodemographic background of the women in this study. Children born preterm or with low birth weight had a 3-fold likelihood to be delivered by caesarean section. Women who had an elective caesarean section were older than the women who had a vaginal delivery, and young mothers were more likely to give birth vaginally. The caesarean section group consisted of more high-educated women and women with high family income as compared with low-educated women and those with low family income. Women who had a caesarean section were more likely to have a higher BMI than women in the vaginal delivery group.

### Univariate Logistic Regression

The univariate logistic regression analysis evaluated the key exposure "delivery starts by caesarean section" as well as independent variables in relation to caries experience at 3 and 7 y of age and caries increment between 3 and 7 y of age. The analysis showed that the key exposure "delivery starts by caesarean section" exhibited a decreased risk for caries experience at 3 y of age (OR = 0.87, 95% CI = 0.79 to 0.96) and at 7 y of age (OR = 0.85, 95% CI = 0.80 to 0.89), as well as for caries increment between 3 and 7 y of age (OR = 0.86, 95% CI = 0.81 to 0.90) versus "delivery does not start by caesarean section." In addition, all studied covariates—except for gestational weeks, birth weight, and low Apgar score at 3 y of age—were significantly associated with the studied outcomes (Table 3).

**Table 1.**

Caries Experience at 3 and 7 y of Age and Caries Increment between 3 and 7 y of Age in Relation to Mode of Delivery.

Caries Indices	Vaginal Delivery (n = 45,505)	Caesarean Section (n = 9,587)	P Value
<b>Continuous variables</b>			
deft at 3 y of age	0.15 ± 0.78	0.14 ± 0.73	0.007 <sup>a</sup>
deft at 7 y of age	0.72 ± 1.60	0.62 ± 1.49	<0.001 <sup>a</sup>
caries increment 3 to 7 y of age	0.56 ± 1.50	0.46 ± 1.36	<0.001 <sup>a</sup>
<b>Categorical variables</b>			
<b>3 y of age</b>			
deft = 0	42,905	9,106	
deft ≥ 1	2,600	481	0.007 <sup>b</sup>
<b>7 y of age</b>			
deft = 0	34,055	7,464	
deft ≥ 1	11,450	2,123	<0.001 <sup>b</sup>
<b>3 to 7 y of age</b>			
deft = 0	35,020	7,631	
deft ≥ 1	10,485	1,956	<0.001 <sup>b</sup>

Values are presented as mean ± SD or n.  
d, decayed; e, extracted; f, filled; t, teeth.

<sup>a</sup>Mann-Whitney U test.

<sup>b</sup>Pearson chi-square test.

### Multivariate Logistic Regression

Table 4 presents the results of multivariate logistic regression analyses of the associations between the key exposure “delivery starts by caesarean section” and caries experience at 3 y of age and at 7 y of age, as well as the association with caries increment between 3 and 7 y of age. The analysis fitted a multilevel model, adjusting for potential confounders studied in the univariate logistic regression analyses (Table 3). In model 1, the key exposure “delivery starts by caesarean section” in relation to the outcomes was unadjusted. In model 2, adjustments were performed for sex and maternal age. The results showed that “delivery starts by caesarean section” was significantly associated with all studied outcomes. Model 3 was adjusted for potential confounders of child

characteristics (weeks of pregnancy, birth weight, Apgar score, and parity). Despite the adjustments in model 3, the variable “delivery starts by caesarean section” was still negatively and significantly associated with caries experience at 3 y of age, at 7 y of age, and between 3 and 7 y of age. In model 4, potential maternal-related sociodemographic confounders were entered into the model (country of birth, educational level, BMI ≥25, smoking in early pregnancy, and family income). In this model, the association between “delivery starts by caesarean section” and caries experience at 3 y of age was no longer statistically significant. Finally, in model 5, all groups of potential confounders were entered in the analysis. The results still showed significant associations between the key exposure “delivery starts by caesarean section” and caries experience at 7 y of age (OR

= 0.90, 95% CI = 0.84 to 0.95) as well as caries increment between 3 and 7 y of age (OR = 0.91, 95% CI = 0.85 to 0.97). No statistically significant associations were observed between “delivery starts by caesarean section” and caries experience at 3 y of age (OR = 0.92, 95% CI = 0.82 to 1.04).

To control for confounding, additional multivariate logistic regression analyses were performed concerning the outcomes caries experience at 7 y of age and caries increment. In both analyses, low Apgar score and birthweight fell out of the model. Gestational weeks were statistically significant in the final analysis with caries experience at 7 y as the outcome but not with caries increment as outcome. The results showed that “delivery starts by caesarean section” was negatively associated with the outcomes caries experience at 7 y of age (OR = 0.88, 95%

**Table 2.**  
Child Characteristics and Sociodemographic Background in Women with Vaginal Delivery or Caesarean Section.

Variables	Vaginal Delivery (n = 45,505)	Caesarean Section (n = 9,587)	Odds Ratio <sup>a</sup> (95% CI)
<b>Child characteristics</b>			
<b>Sex</b>			
Boys	22,771 (50)	5,072 (53)	1.00
Girls	22,734 (50)	4,515 (47)	0.92 (0.89 to 0.97)
Missing (n = 0)			
<b>Gestational weeks</b>			
≥37	43,673 (96)	8,345 (87)	1.00
<37	1,781 (4)	1,222 (13)	3.26 (3.03 to 3.51)
Missing (n = 51)			
<b>Low Apgar score (at 5 min)</b>			
No	39,553 (87)	7,570 (80)	1.00
Yes	5,634 (13)	1,911 (20)	1.36 (1.29 to 1.44)
Missing (n = 424)			
<b>Birth weight, g</b>			
2,500 to 4,000	35,407 (78)	6,775 (71)	1.00
<2,500	1,120 (2)	981 (10)	3.95 (3.63 to 4.29)
>4,000	8,905 (20)	1,788 (19)	1.04 (0.98 to 1.10)
Missing (n = 116)			
<b>Parity</b>			
1 or 2 children	36,758 (81)	8,032 (84)	1.00
≥3 children	8,747 (19)	1,555 (16)	0.92 (0.87 to 0.98)
Missing (n = 0)			
<b>Sociodemographic background</b>			
<b>Maternal country at birth</b>			
Mother born in Sweden	34,842 (77)	7,429 (77)	1.00
Mother born abroad	10,662 (23)	2,158 (23)	0.96 (0.91 to 1.01)
Missing (n = 1)			
<b>Maternal age at delivery, y</b>			
25 to 34	30,443 (67)	5,942 (62)	1.00
<25	4,919 (11)	545 (6)	0.57 (0.52 to 0.62)
>34	10,143 (22)	3,100 (32)	1.56 (1.49 to 1.64)
Missing (n = 0)			

(continued)

**Table 2.**  
(continued)

Variables	Vaginal Delivery ( <i>n</i> = 45,505)	Caesarean Section ( <i>n</i> = 9,587)	Odds Ratio <sup>a</sup> (95% CI)
<b>Maternal education level, y</b>			
≥13	22,180 (49)	4,781 (50)	1.00
10 to 12	18,556 (41)	3,982 (42)	0.99 (0.95 to 1.04)
≤9	4,705 (10)	816 (8)	0.82 (0.76 to 0.89)
Missing ( <i>n</i> = 72)			
<b>Mother smoked in early pregnancy</b>			
No	37,701 (83)	7,739 (81)	1.00
Yes	3,111 (7)	681 (7)	1.08 (0.99 to 1.17)
Missing ( <i>n</i> = 5,860)			
<b>Maternal body mass index in early pregnancy</b>			
<25.00	26,691 (59)	4,875 (51)	1.00
≥25.00	10,225 (22)	2,690 (28)	1.43 (1.36 to 1.50)
Missing ( <i>n</i> = 10,611)			
<b>Family income, quintile</b>			
First (highest)	8,790 (19)	2,370 (25)	1.00
Second	9,092 (20)	2,068 (21)	0.85 (0.80 to 0.91)
Third	9,230 (20)	1,871 (19)	0.77 (0.72 to 0.82)
Fourth	9,280 (20)	1,778 (19)	0.74 (0.69 to 0.79)
Fifth (lowest)	9,049 (20)	1,492 (16)	0.64 (0.60 to 0.69)
Missing ( <i>n</i> = 72)			

Values are presented as *n* (%).

CI, confidence interval.

<sup>a</sup>Odds ratios of reference categories were set to 1.00.

CI = 0.82 to 0.94) and caries increment between 3 and 7 y of age (OR = 0.88, 95% CI = 0.83 to 0.94). Additional remaining statistically significant variables in the final model—other than “delivery starts by caesarean section”—were sex, parity, country of birth, age at delivery, smoking in early pregnancy, BMI in early pregnancy, educational level, and income (Table 5).

## Discussion

The most important finding in this retrospective register-based cohort study

of Swedish children reveals that children delivered by caesarean section do not represent a group with an increased risk of developing caries in deciduous teeth during preschool age. Noticeably, these children exhibited a decreased risk of developing caries lesions after 3 y of age when compared with vaginally delivered children. Thus, we rejected our hypothesis.

Over the last few years, there has been increased interest in children delivered by caesarean section and their possible risk for developing chronic diseases. In a large

population-based cohort study, children delivered by caesarean section exhibited a significantly increased risk of asthma when compared with vaginally delivered children (Tollanes et al. 2008). It was speculated that the lack of early exposure to maternal microbiota and possible initial colonization with the “wrong” microbes might significantly affect stimulation and maturation of the infant’s immune system, resulting in increased frequency of severe asthma in children (Tollanes et al. 2008). However, as vaginally delivered newborns go through the birth canal, they naturally

**Table 3.**  
Univariate Logistic Regression.

Variables	Odds Ratios <sup>a</sup> (95% CI)		
	3 y	7 y	3 to 7 y
<b>Child characteristics</b>			
<b>Sex</b>			
Boys	1.00	1.00	1.00
Girls	0.91 (0.85 to 0.97)	0.93 (0.90 to 0.96)	0.93 (0.90 to 0.96)
<b>Gestational weeks</b>			
≥37	1.00	1.00	1.00
<37	0.96 (0.84 to 1.10)	0.93 (0.86 to 1.01)	0.95 (0.88 to 1.03)
<b>Delivery starts by caesarean section</b>			
No	1.00	1.00	1.00
Yes	0.87 (0.79 to 0.96)	0.85 (0.80 to 0.89)	0.86 (0.81 to 0.90)
<b>Low Apgar score (at 5 min)</b>			
No	1.00	1.00	1.00
Yes	0.92 (0.84 to 1.01)	0.93 (0.88 to 0.98)	0.93 (0.88 to 0.98)
<b>Birth weight, g</b>			
2,500 to 4,000	1.00	1.00	1.00
<2,500	1.06 (0.89 to 1.25)	0.98 (0.89 to 1.07)	0.96 (0.87 to 1.05)
>4,000	0.96 (0.88 to 1.05)	0.95 (0.91 to 1.00)	0.95 (0.91 to 1.00)
<b>Parity</b>			
1 or 2 children	1.00	1.00	1.00
≥3 children	2.28 (2.12 to 2.45)	2.03 (1.94 to 2.12)	1.21 (1.16 to 1.26)
<b>Sociodemographic background</b>			
<b>Maternal country at birth</b>			
Mother born in Sweden	1.00	1.00	1.00
Mother born abroad	4.27 (3.99 to 4.57)	3.51 (3.37 to 3.65)	3.12 (3.00 to 3.25)
<b>Maternal age at delivery</b>			
25 to 34	1.00	1.00	1.00
<25	2.20 (2.01 to 2.42)	2.27 (2.15 to 2.40)	2.12 (2.01 to 2.24)
>34	1.23 (1.13 to 1.33)	1.09 (1.05 to 1.14)	1.08 (1.03 to 1.12)
<b>Maternal education level, y</b>			
≥13	1.00	1.00	1.00
10 to 12	1.61 (1.49 to 1.74)	1.81 (1.74 to 1.89)	1.74 (1.67 to 1.81)

(continued)

**Table 3.**  
(continued)

Variables	Odds Ratios <sup>a</sup> (95% CI)		
	3 y	7 y	3 to 7 y
≤9	3.95 (3.60 to 4.33)	4.32 (4.07 to 4.59)	3.76 (3.54 to 4.00)
Mother smoked in early pregnancy			
No	1.00	1.00	1.00
Yes	1.94 (1.75 to 2.16)	1.98 (1.85 to 2.11)	1.87 (1.76 to 2.00)
Maternal body mass index in early pregnancy			
<25.00	1.00	1.00	1.00
≥25.00	1.52 (1.41 to 1.64)	1.41 (1.36 to 1.48)	1.37 (1.31 to 1.43)
Family income, quintile			
First (highest)	1.00	1.00	1.00
Second	1.28 (1.12 to 1.46)	1.18 (1.11 to 1.26)	1.15 (1.08 to 1.23)
Third	1.59 (1.40 to 1.80)	1.45 (1.36 to 1.54)	1.41 (1.32 to 1.50)
Fourth	1.98 (1.75 to 2.24)	1.87 (1.76 to 1.99)	1.80 (1.69 to 1.92)
Fifth (lowest)	3.91 (3.49 to 4.38)	3.52 (3.32 to 3.73)	3.15 (2.97 to 3.35)

Univariate logistic regression with caries experience (deft > 0) at 3 and 7 y of age and caries increment (deft > 0) between 3 and 7 y of age as outcomes and child- and parent-related factors during pregnancy and at birth as exposures.

CI, confidence interval; d, decayed; e, extracted; f, filled; t, teeth.

<sup>a</sup>Odds ratios of reference categories were set to 1.00.

**Table 4.**  
Multivariate Logistic Regression Analysis with Key Exposure “Delivery Starts by Caesarean Section” in Relation to Dental Caries.

Outcome	Odds Ratio (95% CI)				
	Model 1 <sup>a</sup>	Model 2 <sup>b</sup>	Model 3 <sup>c</sup>	Model 4 <sup>d</sup>	Model 5 <sup>e</sup>
Caries experience (deft > 0) at 3 y	0.87 (0.79 to 0.96)	0.90 (0.81 to 0.99)	0.90 (0.81 to 0.99)	0.89 (0.80 to 1.01)	0.94 (0.83 to 1.05)
Caries increment ( $\Delta$ deft > 0) 3 to 7 y	0.86 (0.81 to 0.90)	0.89 (0.84 to 0.94)	0.88 (0.83 to 0.93)	0.88 (0.83 to 0.94)	0.91 (0.85 to 0.97)
Caries experience (deft > 0) at 7 y	0.85 (0.80 to 0.89)	0.88 (0.83 to 0.92)	0.87 (0.82 to 0.91)	0.87 (0.81 to 0.92)	0.90 (0.85 to 0.96)

CI, confidence interval; d, decayed; e, extracted; f, filled; t, teeth.

<sup>a</sup>Unadjusted.

<sup>b</sup>Adjusted for sex and maternal age.

<sup>c</sup>Adjusted for child-related factors (weeks of pregnancy, birth weight, Apgar score, parity).

<sup>d</sup>Adjusted for parent-related factors (maternal country of birth, maternal smoking, maternal body mass index, maternal educational level, and family income).

<sup>e</sup>Adjusted for sex, maternal age, child-related factors, and parent-related factors.

acquire a variety of maternal indigenous bacteria, while newborn infants delivered by caesarean section do not (Dominguez-Bello et al. 2010). Based on the arguments that children born by caesarean section

might acquire *Streptococcus mutans* earlier than children born vaginally (Li et al. 2005) and that a higher prevalence of health-related streptococci and lactobacilli has been found in vaginally

delivered infants versus infants delivered by caesarean section (Nelun Barford et al. 2011), children born by caesarean section ought to have a higher risk for dental caries than vaginally born children.



**Table 5.**

Final Multivariate Logistic Regression Analysis with Dental Caries as the Outcome and “Delivery Starts by Caesarean Section” as the Key Exposure.

Variables	Caries Experience, 7 y			Caries Increment, 3 to 7 y		
	OR	95% CI		OR	95% CI	
		Lower	Upper		Lower	Upper
<b>Key variable: delivery starts by caesarean section</b>	0.88	0.82	0.94	0.88	0.83	0.94
<b>Adjusted for child characteristics</b>						
Sex	0.92	0.88	0.96	0.93	0.89	0.97
Parity	1.54	1.46	1.63	1.48	1.40	1.57
Gestational weeks	0.88	0.79	0.98	ns	ns	ns
<b>Adjusted for maternal characteristics</b>						
Country of birth	2.75	2.61	2.89	1.39	1.34	1.44
Age at delivery	1.08	1.05	1.11	1.06	1.03	1.09
Smoking in early pregnancy	1.55	1.43	1.67	1.47	1.36	1.60
Body mass index in early pregnancy	1.12	1.07	1.18	1.09	1.04	1.15
Education level	1.45	1.40	1.45	1.39	1.34	1.44
<b>Adjusted for family characteristics: income</b>	1.15	1.13	1.17	1.14	1.12	1.16

CI, confidence interval; ns, not significant.

However, the results from our study do not support this hypothesis. The lowered risk of caries in children delivered by caesarean delivery is intriguing and seems to point to protective/risk factors other than early colonization of bacteria.

In our study, we included only deliveries that started by caesarean section and not caesarean deliveries that had begun vaginally, because of the risk of exposing the fetus to maternal bacteria in the birth canal due to rupture of the membranes. Many women prefer caesarean section even when it is not medically indicated, and fear of childbirth is one dominant factor in this choice (Nieminen et al. 2009). A possible explanation for our results that children delivered by caesarean section showed lower caries development during preschool age versus vaginally delivered children might be related to feeding habits. It has been reported that the initiation of breast-feeding is lower after a caesarean

birth than a vaginal birth (Prior et al. 2012). Moreover, elective caesarean section seems to lead to shorter period of breast-feeding (Lobel and DeLuca 2007). The first postnatal hours are crucial for establishing mother-infant interaction and breast-feeding success (Winberg 2005). Today, Swedish health care practices recommend that mothers breastfeed their infants as frequently as needed, even at night, if necessary (WHO 2016). When bottle-feeding is introduced, mothers are recommended to feed the infant every 4 h (Weiner 1995). Patterns of behavior that affect dental health, such as oral hygiene and dietary habits, are established early in a child's life and persist during childhood (Ruottinen et al. 2004). However, how breast-feeding influences the feeding pattern in the long run as compared with bottle-feeding is unclear. One possible explanation for our results might be that children delivered by caesarean section are more likely to have been bottle-fed

and, over time, developed more regular dietary habits, resulting in a decreased caries development. In a recent analysis, a marked protective effect of breast-feeding on dental caries was found in children breast-fed up to 12 mo of age. Among those who continued to be breast-fed beyond 12 mo, an increased prevalence of dental caries was found. Among those who were breast-fed beyond 12 mo, there was a further increased risk of dental caries in children who were breast-fed nocturnally (Tham et al. 2015). It has also been reported that children who are breast-fed for longer durations have more frequent cariogenic food intakes (Hallonsten et al. 1995; Feldens et al. 2010). The relationship between breast-feeding and dental caries is complex and contains several confounding factors, such as poor oral hygiene, insufficient exposure to fluoride, intake of sugary products, parental education, and socioeconomic level.

The general health and immunologic benefits of breast-feeding for children are widely recognized (Oddy et al. 2011). In a recently published cohort study, Brennan-Jones et al. (2016) reported a significant protective association between breast-feeding and incidence of otitis media at 3 y of age but not at 6 y of age. The results indicate that the protective effect of breast-feeding may not extend beyond early childhood.

In this study, women in the caesarean section group had a significantly shorter length of pregnancy than women in the vaginal delivery group. In addition, low birth weight and low Apgar score were significantly associated with caesarean section. This shorter pregnancy and low birth weight might have a negative effect on breast-feeding as well as feeding habits, since eating and drinking habits are developed later in preterm children (Bucher et al. 2002) and feeding disturbances have been reported in preterm and low birth weight children (Davenport et al. 2004).

Social determinants play an important role in predicting caries development in children (Twetman and Fontana 2009). Statistics Sweden collects socioeconomic data in national registers that are available for register-based studies, so we decided to include social variables in our logistic regression analyses. The effect size was much attenuated after adjustment for country of birth, education, and income. Additionally, one must take into account a certain unknown residual social confounding factor. Therefore, with allowances for this unknown variable, it seems likely that social confounding explains the lower risk of caries associated with caesarean delivery in this study to a considerable extent.

Similar to Nelun Barfod et al. (2012), we found no significant differences in caries prevalence in 3-y-old children in relation to method of delivery. Concerning caries increment between 3 and 7 y, however, as well as caries prevalence at 7 y of age, our findings are comparable with the results of 2 previous studies. Fontana et al. (2011) found that vaginal birth was a significant

risk predictor for early childhood caries, especially in non-Hispanic African Americans. Similar results were recently reported from a cross-sectional study of a Thai population in which vaginally born children experienced increased caries prevalence as compared with children delivered by caesarean section (Pattanaporn et al. 2013). Interestingly, Pattanaporn et al. (2013) also found that vaginally born children were colonized with higher levels of *S. mutans* when compared with children born by caesarean section. Contradictory to our findings, a previous study showed that baby-bottle tooth decay was diagnosed significantly more often in children delivered by caesarean section (Peretz and Kafka 1997).

The present study used the MBR register as its source of information concerning method of delivery. An advantage of using the MBR is that it covers approximately 97% to 99% of deliveries in Sweden (Gottvall et al. 2014). The quality of the MBR has been evaluated 3 times—in 1976, 1998, and 2001—with the conclusion that it is a valuable source of information for reproductive epidemiology (Cnattingius et al. 1990; Källén et al. 2002). The information on prenatal factors used in the statistical analyses is probably accurate since it was collected prospectively before birth. Furthermore, all information about the family was collected independent of the study outcome, which reduces problems with recall and interviewer bias. An additional strength of this study is that we used an indicator of caesarean delivery that excluded rupture of the membranes. Thus, exposure to maternal bacteria during these deliveries was extremely unlikely.

Register research has certain inherent limitations. In this study, we were not able to include information on levels of oral microorganisms or dietary or oral hygiene habits, since this information is not available in Swedish national registers. In register-based studies, there is a risk of random errors because the diagnosis of manifest caries can

sometimes be under- or overreported due to several examiners. However, random errors are affected by increasing the size of the study and will be reduced to zero if a study becomes infinitely large (Rothman 2002). In this study, the final study cohort consisted of 65,259 children, and the risk of random error is therefore of minor importance. An additional limitation is the dropout rate of 22%. Children who were lost to follow-up exhibited a significantly lower socioeconomic level (i.e., lower educational level and lower family income). Furthermore, the dropouts included a higher proportion of mothers born abroad, mothers who smoked in early pregnancy, and obese mothers. Concerning child characteristics, there were no significant differences between the dropouts and study population.

In conclusion, a significantly decreased caries risk was seen in children delivered by caesarean section at 7 y of age and in children with caries increment between 3 and 7 y of age when compared with children born vaginally.

### Author Contributions

E. Brandquist, contributed to data acquisition, analysis, and interpretation, drafted and critically revised the manuscript; G. Dahllöf, A. Hjern, contributed to design, data analysis, and interpretation, drafted and critically revised the manuscript; A. Julihn, contributed to conception, design, data acquisition, analysis, and interpretation, drafted and critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of the work.

### Acknowledgments

This study was supported by grants from the Swedish Patent Revenue Research Fund. The authors declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

### References

Brennan-Jones CG, Eikelboom RH, Jacques A, Swanepoel W, Atlas MD, Whitehouse AJ,

- Jamieson SE, Oddy WH. 2016. Protective benefit of predominant breastfeeding against otitis media may be limited to early childhood: results from a prospective birth cohort study. *Clin Otolaryngol.* 42(1):29–37.
- Bucher HU, Killer C, Ochsner Y, Vaihinger S, Fauchere JC. 2002. Growth, development milestones and health problems in the first 2 years in very preterm infants compared with term infants: a population based study. *Eur J Pediatr.* 161(3):151–156.
- Conattingius S, Ericson A, Gunnarskog J, Källén B. 1990. A quality study of a medical birth registry. *Scand J Soc Med.* 18(2):143–148.
- Davenport ES, Litenas C, Barbayiannis P, Williams CE. 2004. The effects of diet, breast-feeding and weaning on caries risk for pre-term and low birth weight children. *Int J Paediatr Dent.* 14(4):251–259.
- Dominguez-Bello MG, Costello EK, Contreras M, Magris M, Hidalgo G, Fierer N, Knight R. 2010. Delivery mode shapes the acquisition and structure of the initial microbiota across multiple body habitats in newborns. *Proc Natl Acad Sci U S A.* 107(26):11971–11975.
- Feldens CA, Giugliani ER, Vigo Á, Vítolo MR. 2010. Early feeding practices and severe early childhood caries in four-year-old children from southern Brazil: a birth cohort study. *Caries Res.* 44(5):445–452.
- Fontana M, Jackson R, Eckert G, Swigonski N, Chin J, Zandona AF, Ando M, Stookey GK, Downs S, Zero DT. 2011. Identification of caries risk factors in toddlers. *J Dent Res.* 90(2):209–214.
- Gottvall K, Lundqvist E, Källén K. 2014. Pregnancies, deliveries and newborn infants. The Swedish Medical Birth Register 1973–2014. Assisted reproduction, treatment 1991–2012. Stockholm (Sweden); Socialstyrelsen [accessed 2017 May 24]. <https://www.socialstyrelsen.se/Lists/Artikelkatalog/Attachments/19627/2014-12-19.pdf>
- Hallonsten AL, Wendt LK, Mejåre I, Birkhed D, Håkansson C, Lindvall AM, Edwardsson S, Koch G. 1995. Dental caries and prolonged breast-feeding in 18-month-old Swedish children. *Int J Paediatr Dent.* 5(3):149–155.
- Hyde MJ, Mostyn A, Modi N, Kemp PR. 2012. The health implications of birth by caesarean section. *Biol Rev Camb Philos Soc.* 87(1):229–243.
- Källén B, Källén K, Edlund M, Otterblad-Olausson P. 2002. Utvärdering av det svenska medicinska födelseregistret [accessed 2017 May 24]. [http://www.socialstyrelsen.se/lists/artikelkatalog/attachments/10961/2002-112-4\\_20021124.pdf](http://www.socialstyrelsen.se/lists/artikelkatalog/attachments/10961/2002-112-4_20021124.pdf).
- Koch G. 1967. Effect of sodium fluoride in dentifrice and mouthwash on incidence of dental caries in schoolchildren [dissertation]. Malmö (Sweden): Malmö Högskola.
- Kuhle S, Tong OS, Woolcott CG. 2015. Association between caesarean section and childhood obesity: a systematic review and meta-analysis. *Obes Rev.* 16(4):295–303.
- Li Y, Caufield PW, Dasanayake AP, Wiener HW, Vermund SH. 2005. Mode of delivery and other maternal factors influence the acquisition of *Streptococcus mutans* in infants. *J Dent Res.* 84(9):806–811.
- Lif Holgersson P, Harnevik L, Hernel O, Tanner AC, Johansson I. 2011. Mode of birth delivery affects oral microbiota in infants. *J Dent Res.* 90(10):1183–1188.
- Lobel M, DeLuca RS. 2007. Psychosocial sequelae of cesarean delivery: review and analysis of their causes and implications. *Soc Sci Med.* 64(11):2272–2284.
- Ludvigsson JF, Otterblad-Olausson P, Pettersson BU, Ekblom A. 2009. The Swedish personal identity number: possibilities and pitfalls in healthcare and medical research. *Eur J Epidemiol.* 24(11):659–667.
- Nelun Barfod M, Christensen LB, Twetman S, Lexner MO. 2012. Caries prevalence in danish pre-school children delivered vaginally and by caesarean section. *Acta Odontol Scand.* 70(3):190–193.
- Nelun Barfod M, Magnusson K, Lexner MO, Blomqvist S, Dahlen G, Twetman S. 2011. Oral microflora in infants delivered vaginally and by caesarean section. *Int J Paediatr Dent.* 21(6):401–406.
- Nieminen K, Stephansson O, Ryding EL. 2009. Women's fear of childbirth and preference for cesarean section—a cross-sectional study at various stages of pregnancy in Sweden. *Acta Obstet Gynecol Scand.* 88(7):807–813.
- Oddy WH, Robinson M, Kendall GE, Li J, Zubrick SR, Stanley FJ. 2011. Breastfeeding and early child development: a prospective cohort study. *Acta Paediatr.* 100(7):992–999.
- Pattanaporn K, Saraithong P, Khongkhunthian S, Aleksejuniene J, Laohapensang P, Chhun N, Chen Z, Li Y. 2013. Mode of delivery, *mutans streptococci* colonization, and early childhood caries in three- to five-year-old Thai children. *Community Dent Oral Epidemiol.* 41(3):212–223.
- Peretz B, Kafka I. 1997. Baby bottle tooth decay and complications during pregnancy and delivery. *Pediatr Dent.* 19(1):34–36.
- Prior E, Santhakumaran S, Gale C, Philipps LH, Modi N, Hyde MJ. 2012. Breastfeeding after cesarean delivery: a systematic review and meta-analysis of world literature. *Am J Clin Nutr.* 95(5):1113–1135.
- Rothman K. 2002. Biases in study design. In: *Epidemiology: an introduction.* New York (NY): Oxford University Press. p. 94–95.
- Ruottinen S, Karjalainen S, Pienihäkkinen K, Lagström H, Niinikoski H, Salminen M, Rönnemaa T, Smell O. 2004. Sucrose intake since infancy and dental health in 10-year-old children. *Caries Res.* 38(2):142–148.
- Tham R, Bowatte G, Dharmage SC, Tan DJ, Lau MX, Dai X, Allen KJ, Lodge CJ. 2015. Breastfeeding and the risk of dental caries: a systematic review and meta-analysis. *Acta Paediatr.* 104(467):62–84.
- Thavagnanam S, Fleming J, Bromley A, Shields MD, Cardwell CR. 2008. A meta-analysis of the association between caesarean section and childhood asthma. *Clin Exp Allergy.* 38(4):629–633.
- Tollanes MC, Moster D, Daltveit AK, Irgens LM. 2008. Cesarean section and risk of severe childhood asthma: a population-based cohort study. *J Pediatr.* 153(1):112–116.
- Twetman S, Fontana M. 2009. Patient caries risk assessment. *Monogr Oral Sci.* 21:91–101.
- Wallby T, Hjern A. 2009. Region of birth, income and breastfeeding in a Swedish county. *Acta Paediatr.* 98(11):1799–1804.
- Weiner G. 1995. De räddade barnen: Om fattiga barn, mödrar och fäder och deras möte med filantropin i Hagalund 1900–1940 [dissertation]. Linköping (Sweden): Linköping University.
- WHO.net. 2016. Infant and young child feeding [updated September 2016; accessed May 24, 2017]. <http://www.who.int/mediacentre/factsheets/fs342/en/>.
- Winberg J. 2005. Mother and newborn baby: mutual regulation of physiology and behavior—a selective review. *Dev Psychobiol.* 47(3):217–229.