CLINICAL INVESTIGATIONS

Eruption Stage of Permanent Molars and Occlusal Caries Activity/Arrest

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Abstract: *This study assessed the association between the eruption stage of permanent second molars and occlusal caries activity among 12-year-old schoolchildren from South Brazil. A cross-sectional study was performed in Porto Alegre using a multistage probability sampling strategy to select a representative sample. Clinical examination was conducted to assess the eruption stage of permanent molars, Gingival Bleeding Index, and, after tooth cleaning and drying, caries experience (noncavitated and cavitated lesions, including caries activity assessment). Data were collected on sex, socioeconomic status, mother's education, brushing frequency, and consumption of soft drinks. Generalized estimating equations were used to estimate odds ratios (ORs) and 95% confidence intervals (CIs). Overall, 983 schoolchildren with 3,071 second molars were available for analysis. Whereas active caries was observed in 6.6% of fully erupted permanent second molars, caries affected 26.2%, 29.6%, and 18.2% of erupting molars classified as stages 1, 2, and 3, respectively: stage 1, partially erupted occlusal surface; stage 2, fully erupted occlusal surface, <1/2 crown exposed; and stage 3, fully erupted occlusal surface, >1/2 crown exposed. After adjusting for socioeconomic and behavioral variables, partially erupted molars were significantly more likely to present active caries lesions than molars in full occlusion: stage 1, OR = 4.99 (95% CI = 3.38, 7.38); stage 2, OR = 5.18 (95% CI = 3.14, 8.53); stage 3, OR = 3.20 (95% CI = 2.21, 4.64). Similar results were found when clinical variables were included in the adjusted model. In conclusion, most occlusal caries lesions tend to arrest/revert when teeth reach the occlusal plan; however, an important proportion of these lesions remains active and in need of proper management. Children at risk should be targeted with preventive and minimally invasive strategies.*

Key Words: dental caries, diagnosis, dental occlusion, cross-sectional study, risk assesment, epidemiology.

Introduction

A recent systematic review on caries risk assessment clearly identified posteruptive age as a predictor for caries on permanent teeth—with first molars being at higher risk of occlusal caries within the first year and second molars within the second and third years posteruption (Mejàre *et al.*, 2013). These periods of increased risk coincide with the duration of eruption of first and second permanent molars (Ekstrand *et al.*, 2003). Whereas conventional wisdom and a wealth of anecdotal evidence support an association between eruption stage and dental caries development, relatively few studies have directly investigated this issue (Dirks, 1966; Carvalho *et al.*, 1989; Maltz *et al.*, 2003; Brailsford *et al.*, 2005). In a seminal study, Carvalho *et al.* (1989) showed that the proportion of active lesions decreased whereas the occurrence of arrested lesions increased as molars reached full occlusion. A recent study from our research group showed that partially erupted molars were at higher risk for caries activity than molars in full occlusion (Zenkner *et al.*, 2013). However, this study had important shortcomings, including a convenience sample with homogeneous socioeconomic status and limited statistical adjustment for important cofactors. Collectively, these findings indicate that undisturbed biofilm accumulation is likely responsible for the higher risk of caries on permanent molars under eruption.

To the best of our knowledge, no study in the literature has assessed the relationship between eruption stage and

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occlusal caries using a population-based sample and appropriate data modeling. The validation of the hypothesis that the risk for occlusal dental caries substantially decreases during tooth eruption at the population level could lead policy makers and practitioners to favor preventive measures and minimally invasive treatment for children in this age group. The aim of this study was to assess the association between eruption stage of permanent second molars and occlusal caries activity in a representative sample of 12-year-old schoolchildren from South Brazil.

Materials & Methods

The present analysis was derived from a cross-sectional oral health survey performed in Porto Alegre, southern Brazil, from September 2009 to December 2010. Details about sampling strategy and sample size calculation can be found elsewhere (Alves *et al.*, 2013). In brief, 12-year-old schoolchildren attending 42 schools (33 public and 9 private) participated, totaling a response rate of 83.17% (n = 1,528). The study protocol was approved by the Federal University of Rio Grande do Sul Research Ethics Committee (299/08) and by the Porto Alegre Health Department Research Ethics Committee (process no. 001.049155.08.3/register no. 288), and all participants and their parents/legal guardians provided written informed consent. This study was conducted following STROBE guidelines.

Data Collection

Clinical examinations were conducted at the schools, with the students in a supine position. Portable equipment (artificial light, air compressor, and suction), sterile clinical mirrors, and periodontal probes were used. First, one trained examiner (N.D.-T.) recorded the Gingival Bleeding Index (Ainamo and Bay, 1975), and schoolchildren were submitted to professional tooth brushing and flossing. Then, another examiner (L.S.A.) recorded the eruption stage of permanent second molars and performed caries examination. The eruption stage of permanent second molars was classified as follows (Carvalho *et al.*, 1989):

Stage 0: unerupted.
Stage 1: partially erupted occlusal surface.
Stage 2: fully erupted occlusal surface with less than half of the crown exposed.
Stage 3: fully erupted occlusal surface with more than half of the crown exposed.
Stage 4: full occlusion.

After tooth cleaning and air-drying, tooth surfaces were classified as sound, decayed (cavity), missing, or filled, according to criteria per the World Health Organization (1997). In addition to recording cavitated caries lesions, noncavitated caries lesions and caries activity were recorded as follows (Maltz *et al.*, 2003):

Active noncavitated lesions: tooth surfaces with opaque enamel and dull-whitish color/appearance.
Inactive noncavitated lesions: surface areas presenting a shiny appearance with different degrees of brownish discoloration.
Active cavitated lesions: localized surface destruction with active characteristics (dull-whitish enamel and soft dentin with light brown color).
Inactive cavitated lesions: localized surface destruction with arrested characteristics (shiny, hard surfaces with different degrees of brownish discoloration).

Two standardized questionnaires were used to collect data regarding the predictor variables. One was sent to parents/legal guardians of each selected student to collect data on socioeconomic status, mother's educational level, and brushing frequency of children. Students answered the other questionnaire on dietary habits, including the frequency of consumption of soft drinks.

Reproducibility

Before the beginning of the study, the examiner trained by assessing photographs and clinical examinations. Assessment of reproducibility before and during the survey was conducted by means of repeated examinations on 61 schoolchildren with a minimal time interval between examinations of 2 d. Cohen kappa values (unweighted) ranged from 0.8 to 0.9 for caries examination and from 0.9 to 1.0 for eruption stage.

Data Analysis

The primary outcome of this study was the presence of active caries lesions on the occlusal surfaces of permanent second molars, which was defined as a binary variable: *absent*, when the occlusal surface was sound, presented inactive caries lesions (noncavitated, cavitated, or dark shadow from dentine) or sealants; *present*, when the occlusal surface presented active caries lesions (noncavitated or cavitated) or fillings. Filled molars were classified as active lesions based on the assumption that these surfaces had presented lesion progression to the point that a dental filling was indicated. The main predictor variable was the eruption stage, and stage 4 (full eruption) was the reference category.

Socioeconomic status was categorized with cutoff points proposed by the standard Brazilian economic classification (ABEP, 2009): low (≤13 points), midlow (≥14 to ≤22 points), midhigh (≥23 to ≤28 points), and high (≥29 points). Mother's education was dichotomized into ≤8 yr (elementary/middle school) and >8 yr (high school/university). Soft drink consumption was classified as nondaily and daily. Brushing frequency was categorized as follows: ≤1, 2, and ≥3 times per day (Alves *et al.*, 2013). Gingivitis was categorized according to the percentage of sites with bleeding on probing (<30%, ≥30% to <50%, ≥50% to <75%, and ≥75%) and used as a proxy for biofilm control. Schoolchildren were classified according to their caries experience based on the DMF-T (decayed, missing, and filled teeth) index (cavitated lesions + active noncavitated lesions): 0, 1-4, and ≥5. Permanent second molars were

not included in the calculation of the DMF-T index.

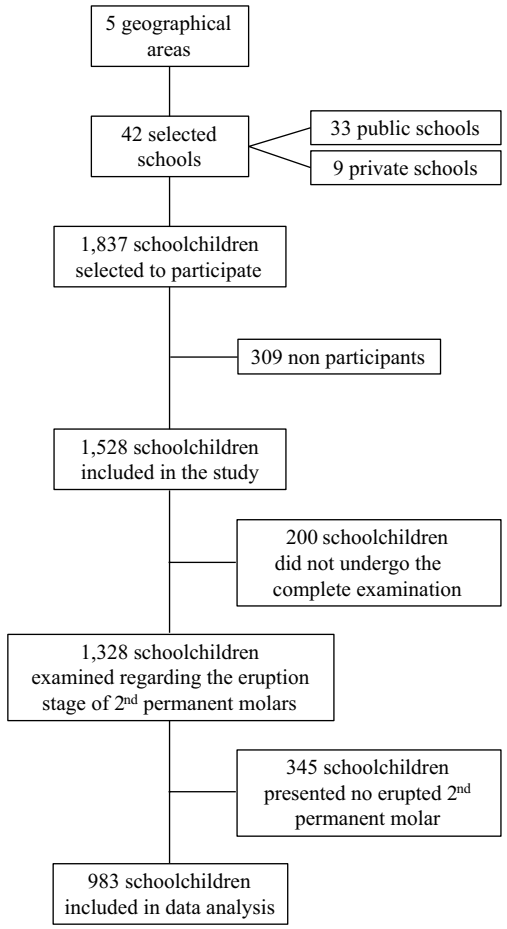
Preliminary analysis on the association between occlusal caries activity and eruption stage was performed via the chi-square test adjusted for clustering of observations within subjects. Generalized estimating equations were used to model this association while accounting for the clustering of teeth within subjects. The tooth was used as the unit of analysis. Generalized estimating equations with an exchangeable working correlation, logit link, and semirobust standard errors were used to estimate odds ratios and their respective 95% confidence intervals. Unadjusted and adjusted analyses were performed. First, estimates were adjusted for sociodemographic and behavioral variables, including sex, socioeconomic status, mother's education, soft drink consumption, and brushing frequency (adjusted model 1). An additional analysis was conducted adding gingivitis and DMF-T as adjusting variables (adjusted model 2). The data were analyzed with SPSS 17.0.

Results

Data on the eruption stage of permanent second molars were collected in 1,328 individuals, of whom 983 had erupted permanent second molars (Figure, Table 1). A total of 3,071 teeth were included in the analysis. Table 2 shows the distribution of permanent second molars according to eruption stage and occlusal caries activity. Overall, active caries lesions were detected in 17.2% of the examined teeth. A clear decrease in the percentage of permanent second molars with active occlusal caries was observed with increasing stages of eruption. Whereas more than a quarter of the permanent second molars classified as stage 1 or 2 were diagnosed with occlusal caries, active caries was observed in 6.6% of fully erupted molars (Table 2).

Table 3 shows the association between eruption stage of permanent second molars and occlusal caries activity adjusted for important cofactors. After adjusting for sociodemographic and behavioral factors (Table 3, adjusted model 1), eruption stage was significantly associated with occlusal caries activity in this population. Compared with permanent second molars in full occlusion (stage 4), partially erupted molars (stage 1) and molars with less than half their crowns exposed to the oral cavity (stage 2) were 5 times more likely to have active caries. In comparison, permanent second molars with more than half their crowns exposed to the oral cavity (stage 3) were 3 times more likely to have active caries than fully erupted molars (stage 4). Whereas a clear linear relationship between eruption stage and caries activity was not observed, a significant decrease in the odds of having active caries was observed when molars reached eruption stage 3 in comparison with stage 1 ($p = .02$) and stage 2 ($p = .01$). When gingivitis and DMF-T were added to the model (Table 3, adjusted model 2), a slight increase in the risk estimates was observed.

Figure.
Flowchart of the study.



Discussion

This study was conducted to assess the association between eruption stage of permanent second molars and occlusal caries activity in a population-based sample of 12-year-old schoolchildren from South Brazil. Erupting molars had higher risk for active occlusal caries than molars in full occlusion, and this association was not affected by sociodemographic, behavioral, or clinical variables.

The present study showed that the proportion of occlusal active lesions decreased significantly as the tooth

Table 1.
Sample Description at the Individual Level

	n	%
Sex		
Female	536	54.5
Male	447	45.5
Socioeconomic status		
High	98	10.0
Midhigh	228	23.2
Midlow	554	56.3
Low	103	10.5
Mother's education, yr[a]		
≤8	133	13.6
>8	844	86.4
Soft drinks consumption		
Nondaily	703	71.5
Daily	280	28.5
Brushing frequency per day		
≤1	202	20.5
2	443	45.1
≥3	338	34.4
Gingivitis (bleeding sites),[b] **%**		
<30	79	8.0
≥30 to <50	323	33.0
≥50 to <75	481	49.1
≥75	97	9.9
DMF-T[c]		
0	458	46.6
1-4	463	47.1
≥5	62	6.3
Total	983	100

[a]Figures do not total 983 because of missing data.
[b]Gingival bleeding index was not performed in 3 individuals with heart disease.
[c]DMF-T (decayed, missing, and filled teeth) includes cavitated lesions and active noncavitated lesions.

approached the occlusal plan. Around a quarter of molars under eruption presented active caries, decreasing to 6.6% in molars in full occlusion, which suggests that most lesions tend to arrest when the tooth achieves occlusal function. Despite these findings, a relevant proportion of molars remained caries active even in the presence of occlusal contact, justifying the need for special care during the eruptive period. In the risk assessment analysis, molars with eruption stages 1, 2, and 3 presented a risk for occlusal active caries lesions 3- to 6-fold higher than molars with stage 4, which is in agreement with the results by Zenkner *et al.* (2013). It is important to emphasize that fluoridated water and toothpaste are readily available to this population; thus, extrapolation of our findings to other populations should be done with caution.

Favorable conditions for biofilm accumulation during tooth eruption are likely to explain, at least in part, the present findings. First, the amount of biofilm accumulated on the occlusal surfaces has been shown to be higher in partially erupted molars than in fully erupted molars (Carvalho *et al.*, 1989; Brailsford *et al.*, 2005; Zenkner *et al.*, 2013). In addition, Brailsford *et al.* (2005) showed qualitative differences in the biofilm composition, with partially erupted teeth having higher counts of non–mutans streptococci and *Actinomyces israelii* than fully erupted teeth. These quantitative and qualitative changes on the biofilm are potentiated by the lack of knowledge of the presence of permanent second molars by the child and caregivers, as well as difficult access for daily care. As the eruption process evolves, the functional use and improved access reduce the caries risk.

In the multivariable analysis, the association between occlusal caries and eruption stage was adjusted for well-known risk factors for caries. Interestingly, socioeconomic and behavioral factors had modest if any effect on the association estimates. Noteworthy, the adjusted estimates were higher than the unadjusted estimates, which is counterintuitive since a decrease in the strength of the association should be expected. We also attempted to take into consideration oral hygiene as measured by gingivitis and caries experience. Whereas the appropriateness of including past caries experience could be criticized (Tu *et al.*, 2005; Aleksejuniene *et al.*, 2009), adjusted estimates were remarkably similar to the crude estimates highlighting the importance of eruption stage for the occurrence of occlusal caries in permanent second molars.

Noteworthy strengths of our study include the large population-based sample of 12-year-old schoolchildren, the clinical examination protocol encompassing tooth cleaning and drying for better detection of noncavitated lesions, and the high reproducibility of the examiner. A model-based analysis (Hosmer *et al.*, 2013) using generalized

Table 2.
Distribution of Permanent Second Molars According to Eruption Stage and Occlusal Caries Activity, *n* (%)

Caries Activity	Eruption Stage				Total
	1	2	3	4	
No					
Sound	526 (72.1)	108 (66.7)	814 (67.2)	694 (71.7)	2,142 (69.7)
Inactive noncavitated	9 (1.2)	5 (3.1)	148 (12.2)	164 (16.9)	326 (10.6)
Inactive cavitated	1 (0.1)	1 (0.6)	20 (1.7)	31 (3.2)	53 (1.7)
Dark shadow from dentine	0	0	6 (0.5)	13 (1.3)	19 (0.6)
Sealed	0	0	2 (0.2)	2 (0.2)	4 (0.1)
Total*	536 (73.4)	114 (70.4)	990 (81.8)	904 (93.4)	2,544 (82.8)
Yes					
Active noncavitated	184 (25.2)	43 (26.5)	179 (14.8)	48 (5.0)	454 (14.8)
Active cavitated	10 (1.4)	5 (3.1)	35 (2.9)	15 (1.5)	65 (2.1)
Filled	0	0	7 (0.6)	1 (0.1)	8 (0.3)
Total*	194 (26.6)	48 (29.6)	221 (18.2)	64 (6.6)	527 (17.2)

*$p < .01$. Chi-square test for total number of lesions according to eruption stage, adjusted for clustering of observation within children.

Table 3.
Association between Eruption Stage of Permanent Second Molars and Occlusal Caries Activity among 12-Year-old Schoolchildren

Stage	Unadjusted Model			Adjusted Model 1[a]			Adjusted Model 2[b]		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
1	4.74	3.23, 6.97	<.01	4.99	3.38, 7.38	<.01	5.48	3.66, 8.21	<.01
2	5.05	3.08, 8.26	<.01	5.18	3.14, 8.53	<.01	5.72	3.40, 9.62	<.01
3	3.12	2.16, 4.51	<.01	3.20	2.21, 4.64	<.01	3.33	2.28, 4.87	<.01
4[c]	1.00			1.00			1.00		

OR, odds ratio; CI, confidence interval.
[a]Estimates adjusted for sex, socioeconomic status, mother's education, soft drink consumption, and brushing frequency.
[b]Estimates adjusted for sex, socioeconomic status, mother's education, soft drink consumption, brushing frequency, gingivitis, and DMF-T (decayed, missing, and filled teeth).
[c]Full occlusion.

estimating equations (Desai and Begg, 2008) was carried out to account for the clustering of observations within subjects. Whereas this analytic approach provided the necessary adjustment for the strong correlation observed among teeth within children (intraclass correlation coefficient ~ 0.30), it did not take into consideration the study design. An exploratory multivariable analysis including municipal fluoridation areas and schools was performed in an effort to estimate the design effect on estimates. Since only modest increases in the odds ratios were observed, estimates not adjusted for the study design are reported herein. The cross-sectional nature may be seen as a shortcoming of this study.

In conclusion, the present study provides strong evidence of the association between eruption stage and occlusal caries activity at the population level. Erupting molars were at higher risk for caries activity than molars in functional occlusion. Although most occlusal caries lesions tend to arrest/revert when teeth reach the occlusal plan, an important proportion of these lesions remain active and in need of proper management. Children at risk should be targeted with preventive and minimally invasive strategies.

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