

Decision tree analysis for factors associated with dental caries in school-aged children in Japan

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Objective: Our study aimed to elucidate the interactive relationship between factors associated with dental caries in school children using decision tree analysis. **Research Design:** Cross-sectional study **Methods:** Participants were recruited from public primary schools (9–12 years, 4th to 6th grade) and junior high schools (12–13 years, 1st grade) in Japan. A total of 1775 students (928 boys and 847 girls) were analyzed. Questionnaire survey, oral examination, and saliva test were performed. Multiple logistic regression and decision tree analysis were performed. **Results:** Multiple logistic regression showed an association between dental caries and toothpaste use, dental attendance and the presence of *Streptococcus mutans*. Decision tree analysis showed that students with non-regular dental attendance were at a significantly higher risk of dental caries at the late stage of primary school. At the early stage of primary school, high levels of *Streptococcus mutans* and male sex were factors associated with dental caries. In students with low levels of *Streptococcus mutans*, using toothpaste occasionally was associated with a high risk of dental caries. **Conclusions:** In early primary school years, *S. mutans* may be a useful screening and diagnostic tool for dental caries. In students with high levels of *S. mutans*, sex may be associated with dental caries. Furthermore, in students with low levels of *S. mutans*, regular use of toothpaste should be encouraged, and in late primary school years, regular dental attendance should be encouraged to prevent dental caries.

Keywords: Dental caries, epidemiology, children, schoolchildren, dental attendance

Introduction

Dental caries is the most prevalent oral disease in children (Selwitz *et al.*, 2007), and main cause of tooth pain and loss (Bansal *et al.*, 2017). Early caries occurrence has been associated with the future development of dental caries in children (Masood *et al.*, 2012). Therefore, prevention of dental caries in childhood is an effective way to prevent future tooth loss.

Several factors including the presence of *Streptococcus mutans*, diet, oral hygiene, regular dental attendance, saliva and use of fluorides have been associated with dental caries in young children (Harris *et al.*, 2004; Selwitz *et al.*, 2007). Harris and colleagues reported that in children, early acquisition of *S. mutans* is most likely associated with the development of dental caries (Harris *et al.*, 2004). However, this may be partly compensated by good oral hygiene and a non-cariogenic diet. In addition, several factors, including those stated above, were recently reported to be associated with early childhood caries (Gao *et al.*, 2018). Accordingly, the factors associated with dental caries may interact with each other. However, few studies have investigated the interactive relationships between factors associated with dental caries and the occurrence of dental caries. To reveal this relationship, we used decision tree analysis. Although logistic regression is useful to find risk factors throughout the population, decision tree analysis enables

the division of the population into subgroups with different characteristics. In addition, decision tree analysis enables inclusion of multiple independent variables to establish a predictive model. We assumed that this analysis would be useful to reveal interactive relationships between factors associated with dental caries and the occurrence of dental caries. Revealing this relationship may help prevent or reduce dental caries in childhood.

School-based programs involving the use of fluorides have been effective in preventing dental caries (Dudovitz *et al.*, 2018). Therefore, this study focused on primary and junior high school students. The aim of our study was to elucidate the interactive relationships between factors associated with dental caries and its occurrence, and to highlight effective strategies to prevent dental caries in school-aged children by using decision tree analysis.

Methods

Participants were recruited from public primary and junior high schools in Ichikawa city, Chiba, Japan. The Ichikawa Dental Association has conducted a dental check-up and self-reported questionnaire survey in some schools since 2008. Among these schools, results from fifteen public primary schools and four junior high schools in 2009 and 2010 were available for this study. In total, 2161 students took part including 4th,

5th and 6th grade primary school students (aged 9–10, 10–11 and 11–12 years respectively) and 1st graders (12–13 years of age) from junior high schools. Data for 386 students were excluded from the analysis due to missing responses, leaving 1775 students (928 boys and 847 girls) to be analyzed. All students and parents or caregivers gave written informed consent for participation. The study protocol was approved by the ethical committee of Tokyo Dental College (Approval number: 657).

Questionnaire

The students answered a self-reported questionnaire. The frequency of daily brushing was determined using the question “How often do you brush your teeth in a day?” The response was categorized as frequency of brushing <2 or ≥2. Information was also collected on the use of toothpaste (“Do you use toothpaste?” Responses were categorized as sometimes or every time), sugar sweetened snacks (“How often do you eat sugar sweetened snacks?” categorized as not daily or daily), sugar sweetened beverages (“How often do you drink sugar sweetened beverages?” categorized as not daily or daily) and regular dental attendance (“Do you have regular dental check-ups?” categorized as yes or no).

Oral examination

Data on decayed and filled teeth in the deciduous (df teeth) and permanent dentitions (df and DF respectively) were obtained from the dental check-ups conducted by the Ichikawa Dental Association. This dental check-up was regulated by Japanese law (School Health and Safety Act). The dentists of the Ichikawa Dental Association had opportunities to attend workshops for oral examination in school settings. Based on the manual created by the Japanese Association of School Dentists (2015), dental caries was monitored clinically by visual examination and with a community periodontal index probe. Decay was defined as a carious lesion with obvious cavitation.

Saliva samples

Salivary *S. mutans* count was determined by using a simple chair-side monoclonal antibody method (Matsumoto *et al.*, 2006). The students were divided into two groups; with counts +/-10⁵ CFU/ml, based on a previous study (Osawa *et al.*, 2015). Paraffin-stimulated whole saliva samples were collected from the students during chewing for 3 min in the morning. Salivary flow rate (ml/min) was analyzed as a continuous variable.

Statistical analysis

Data were summarized as mean ± standard deviation. The distribution of participants with factors associated with dental caries was determined using chi-squared and Student's t-tests. Forward selection logistic regression analysis was performed to identify the factors associated with the presence of dental caries. The dependent variable was the presence of dental caries in the deciduous or permanent dentition. After adjustment for sex and age, frequency of tooth brushing, use of toothpaste, sugar sweetened snacks, sugar sweetened beverages, regular dental attendance, presence of *S. mutans*, and saliva flow rate were included as independent variables. Decision tree analysis was performed to identify the interaction of factors associated with dental caries. For this analysis,

the Chi-Squared Automatic Interaction Detection (CHAID) algorithm (based on the chi-squared tests) (Kass, 1980) was used to identify relationships between one dependent variable and several independent variables. The data were analyzed by using SPSS, version 25.0 (SPSS Japan, Inc. Tokyo, Japan), and significance was considered at $p < 0.05$.

Results

Table 1 shows the mean number of df, DF and df + DF teeth by sex and age. In both sexes, 9–10 year-old students had the highest mean df; 12–13-year-old students had the smallest mean df. Differences between sexes were observed among all age groups in the number of df teeth, and in 11–12-year-old students and 12–13-year-old students in the number of DF teeth. Furthermore, 10–11-year-old students had the highest average number of DF teeth in males, and 12–13-year-old students had the highest average number of DF teeth in females. The 9–10-year-old students had the highest average number of df + DF teeth in both sexes.

Table 2 shows the factors associated with the presence of DF and df teeth in bivariate analyses. Older students and those who used toothpaste sometimes, did not attend the dentist regularly and had *S. mutans* count ≥ 10⁵ CFU/ml were more likely to have decayed and filled teeth in the deciduous or permanent dentition.

Table 3 shows the result of the multiple logistic regression analysis for factors associated with the presence of decayed and filled teeth in the deciduous or permanent dentition. After adjusting for sex and age, following 3 factors remained in the model: use of toothpaste (odds ratio [OR], 1.4; 95% confidence interval [CI], 1.1–1.8), regular dental attendance (OR, 1.3; 95% CI, 1.1–1.6), and high *S. mutans* counts (OR, 1.6; 95% CI, 1.2–2.0).

Figure 1 depicts the decision tree analysis for factors associated with the presence of decayed and filled teeth in the deciduous or permanent dentition. Among 11–13-year-old students, greater risk of dental caries was observed in non-regular dental attenders. Among 10–11-year-old students and younger students, *S. mutans* count ≥ 10⁵ CFU/ml and male sex were associated with dental caries. In students who used toothpaste sometimes, *S. mutans* counts < 10⁵ CFU/ml were associated with dental caries.

Discussion

This study showed the interactive relationships between the factors associated with dental caries and the occurrence of dental caries and treatment experience. Multiple logistic regression revealed that greater age, less frequent use of toothpaste, irregular dental attendance, and high *S. mutans* counts were associated with the presence of dental caries and fillings. In addition, decision tree analysis revealed that the presence of *S. mutans* was interactively associated with the use of toothpaste and sex in 10–11-year-old students and younger students.

The timing of acquiring *S. mutans* has been associated with caries risk (Harris *et al.*, 2004). Children acquiring *S. mutans* at an early age are most likely develop caries in future. In addition, high *S. mutans* levels have been regarded as a high risk for dental caries (Vehkalahti *et al.*, 1996). In the present study, we showed that *S. mutans* was associated with dental caries among young age school students.

Table 1. Decayed and filled deciduous permanent teeth by sex and age

	<i>n</i>		<i>Number of df teeth</i>			<i>Number of DF teeth</i>			<i>Number of df + DF teeth</i>		
	Male	Female	Male	Female	<i>p</i> (<i>t test</i>)	Male	Female	<i>p</i> (<i>t test</i>)	Male	Female	<i>p</i> (<i>t test</i>)
9–10 years of age	140	97	2.7±2.7	1.9±2.3	0.02	0.4±0.9	0.4±0.9	0.89	3.0±3.0	2.3±2.7	0.05
10–11 years of age	328	329	1.5±2.1	1.2±1.9	0.02	1.1±1.5	1.0±1.8	0.69	2.6±2.9	2.2±2.9	0.73
11–12 years of age	161	176	0.6±1.4	0.4±1.0	0.04	0.7±1.2	1.0±1.8	0.04	1.3±2.1	1.4±2.1	0.76
12–13 years of age	299	245	0.3±0.8	0.1±0.4	0.01	0.8±1.5	1.1±1.8	0.06	1.1±1.8	1.2±1.9	0.42

Data are presented as mean±standard deviation. df, decayed and filled teeth in deciduous dentition; DF, decayed and filled teeth in permanent dentition

Table 2. Factors associated with the presence of df and DF teeth

		<i>Presence of df or DF teeth</i>				<i>p</i>
		<i>Yes</i>		<i>No</i>		
		<i>n</i>	%	<i>n</i>	%	
Sex	Male	494	53.2	434	46.8	0.20*
	Female	426	50.3	421	49.7	
Age (years)	9–10	155	65.4	82	34.6	<0.01*
	10–11	390	59.4	267	40.6	
	11–12	153	45.4	184	54.6	
	12–13	222	40.8	322	59.1	
Tooth brushing	<2	194	54.8	160	45.2	0.20*
	≥2	726	51.1	695	48.9	
Use of toothpaste	Every time	754	50.3	744	49.7	<0.01*
	Sometimes	166	59.9	111	40.1	
Sugar sweetened snacks	Not daily	830	51.6	777	48.4	0.60*
	Daily	90	53.6	78	46.4	
Sugar sweetened beverages	Not daily	754	51.8	701	48.2	1.00*
	Daily	166	51.9	154	48.1	
Regular dental attendance	Yes	300	47.0	338	53.0	<0.01*
	No	620	54.6	517	45.4	
<i>Streptococcus mutans</i>	<10 ⁵ CFU/ml	687	49.2	709	50.8	<0.01*
	≥10 ⁵ CFU/ml	233	61.5	146	38.5	
Salivary flow rate (ml/min)		1.3±0.7		1.4±0.8		0.09**

df, decayed and filled teeth in deciduous dentition; DF, decayed and filled teeth in permanent dentition

*, Chi-squared test; **, t-test

Table 3. Multiple logistic regression for factors associated with the presence of decayed and filled teeth in the deciduous or permanent dentition

		<i>OR</i>	<i>95% CI</i>
Sex	Male	1.0	
	Female	0.9	0.8-1.1
Age (years)	9–10	1.0	
	10–11	0.8	0.6-1.1
	11–12	0.5	0.3-0.7
	12–13	0.4	0.3-0.5
Use of toothpaste	Every time	1.0	
	Sometimes	1.4	1.1-1.8
Regular dental attendance	Yes	1.0	
	No	1.3	1.1-1.6
<i>Streptococcus mutans</i>	<10 ⁵ CFU/ml	1.0	
	≥10 ⁵ CFU/ml	1.6	1.2-2.0

OR, Odd ratio; CI, Confidence interval

In students with low levels of *S. mutans*, regular use of toothpaste was significantly associated with lower dental caries. The use of fluoride toothpaste has been reported to be effective for all children and adolescents to prevent dental caries (Rasines, 2010). Therefore, among students with low levels of *S. mutans*, using toothpaste occasionally might be strongly associated with a high risk of dental

caries. Moreover, over 90% of toothpaste sold in Japan contains fluorides (The Lion Foundation For Dental Health, 2016). It is reasonable to assume most of our participants used a fluoride toothpaste although some Japanese children use non-fluoride toothpaste (Ota *et al.*, 2013). Our results suggest that regular use of fluoride toothpaste may be more effective in children, especially in those with low levels of *S. mutans* in early primary school years.

In students with high levels of *S. mutans*, sex was significantly associated with dental caries. Previously Richardson *et al.*, (1995) reported that females had higher *S. mutans* count than males. The authors also found no significant difference in the number of decayed, filled, and missing teeth between males and females. However, epidemiological studies report more caries in females than in males (Lukacs, 2011). In our study, more males had dental caries than females in the young group with high levels of *S. mutans*. Furthermore, some studies indicate no sex differences in dental caries in children aged 6–12 years (Lukacs, 2011). The target population of our study was this age. We found similar numbers of df + DF teeth in both sexes (Table 1). However, in the young group with high levels of *S. mutans*, males had more dental caries than females. In our study, males had significantly higher number of df teeth, compared with females. The difference in numbers of df teeth was highest among children 9–10 years of age.

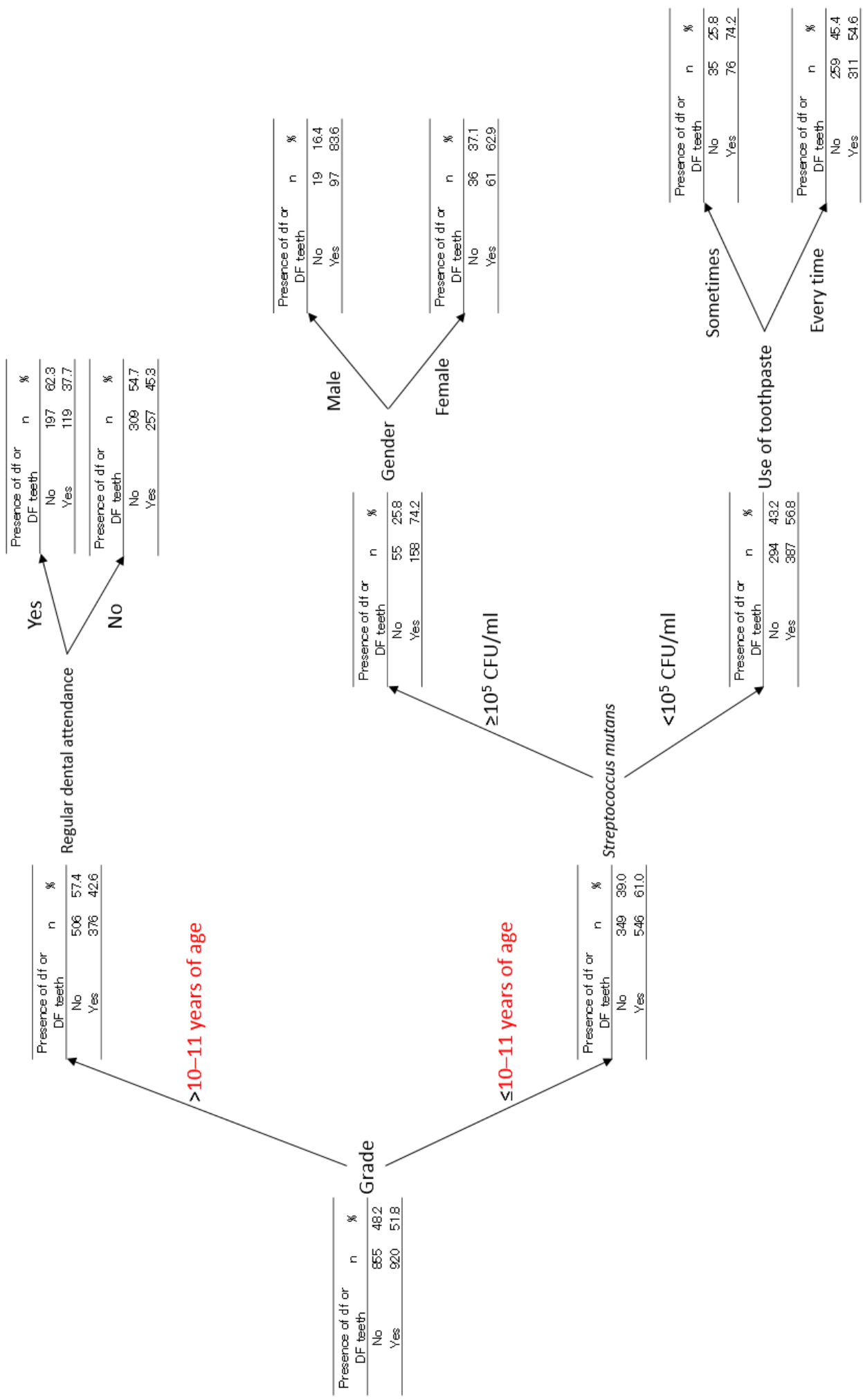


Figure 1: Decision tree analysis for factors associated with the presence of decayed and filled teeth in the deciduous or permanent dentition.

Greater severity of dental caries has been associated with high levels of *S. mutans* (Relvas *et al.*, 2014). In addition, the replacement of deciduous teeth in females occurs earlier than males. Therefore, sex may be associated with dental caries among 9–11-year-old students with high levels of *S. mutans* due to the high number of df teeth among males in our study.

In children, regular dental attendance is encouraged for early caries detection (Badri *et al.*, 2014). However, some systematic reviews have shown only weak evidence of preventing dental caries by regular dental attendance (Patel *et al.*, 2010). In our study, regular dental attendance was associated with lower caries levels in students above 10–11 years of age. The students who attended regularly were less likely to have caries or fillings than those who attended irregularly (Table 2). Therefore, regular dental attendance might be associated with a lack of dental caries in students with late stages of mixed dentition. In regard to the frequency of regular dental attendance, Riley *et al.*, reported that the effect on dental caries of a 12-month vs. 24-month interval for dental visits did not differ (Riley *et al.*, 2013). Therefore, regular dental attendance at least once per year should be encouraged to prevent dental caries in late primary school years.

This study has some limitations. First, oral examination was performed by several dentists. Therefore, our results are subject to inter-examiner errors. However, the level of caries observed was relatively reasonable, and upon comparison was consistent with data from the Survey of Dental Diseases in Japan (Japanese Ministry of Health, Labour and Welfare, 2011). Second, the participating schools were not randomly selected. Therefore, selection bias might have affected our results. Third, the questionnaire was answered by the students themselves. Hence, the responses might have been inaccurate. Additional data collection from parents might be effective for future studies.

In conclusion, we showed that there are interactive relationships between factors associated with dental caries and the occurrence of dental caries. In early primary school years, the presence of *S. mutans* could be a useful screening and diagnostic tool for dental caries. For example, a rapid and quantitative detection system for *S. mutans* has been developed (Matsumoto *et al.*, 2006). This system detects *S. mutans* in 30 minutes and stratifies the results into three levels.

In students with high levels of *S. mutans*, sex may be associated with dental caries. In students with low levels of *S. mutans*, regular use of toothpaste should be encouraged, and in late primary school years, regular dental attendance should be encouraged to prevent dental caries.

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