

Scientific Research Report

Effect of a School-based Fluoride Mouth-rinsing Programme on Dental Caries

Daisuke Yonezawa^{a*}, Minoru Yagi^b^a Department of Oral Health and Welfare, Faculty of Dentistry & Graduate School of Medical and Dental Sciences, Niigata University, Niigata, Japan^b Sanjo Nursing, Medical Office Assistant, Dental Hygienist College, Niigata, Japan

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ABSTRACT

Aims: The objective of this study was to evaluate the posttreatment effects of a school-based fluoride mouth-rinsing programme (FMR) on the prevalence of dental caries.**Methods:** We included 364 newly enrolled university students aged 20 to 25 years who were not in any FMR and 187 students who had previously participated in such programmes. We calculated the prevalence of dental caries in permanent teeth and the mean decayed, missing, and filled surfaces (DMFS) according to sex, age, participation in FMR, and dental health behaviours. A multivariate logistic regression model was used to analyse the association between dichotomous variables (caries present or absent) and demographic data, participation in FMR, and dental health behaviours.**Results:** The difference in the prevalence of dental caries in permanent teeth between the subjects who participated in the FMR (51.3%) and those who did not (64.5%) was statistically significant. There were 39.6% fewer DMFS in the subjects who participated in the FMR at least during elementary school. The multivariate logistic regression model analysis demonstrated that subjects who participated in the FMR at least during elementary school were protected against dental caries as compared to those who did not. Age and sex were risk predictors of dental caries in adults, whilst other variables were not associated with dental caries.**Conclusions:** Participation in an FMR at least during elementary school is a predictor for the reduction in the prevalence of dental caries in permanent teeth.

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Introduction

Mouth-rinsing with a verified fluoride concentration of sodium fluoride solution daily, weekly, or fortnightly is a feasible and effective method for the prevention of dental caries in schoolchildren.¹ An early study showed that children in a fluoride-rinse group were protected on all types of tooth surfaces.² Previous studies strongly indicate that long-term rinsing with fluoride has a positive effect on the teeth status.³⁻⁵ School-based fluoride mouth-rinsing programmes (FMR) are recommended in low-fluoride communities where caries

activity ranges from moderate to high; however, they are not recommended in optimally fluoridated communities and are contraindicated in children younger than 6 years. This is because fluoride rinsing might contribute to dental fluorosis, depending on the total amount of fluoride ingested daily, although the retained amount of diluted fluoride solution following correct rinsing would not cause dental fluorosis in a preschool-aged child.⁶ Despite only a few areas being naturally fluoridated, none of the communities in Japan have implemented a method that artificially adjusts the fluoride concentration in drinking water for the prevention of dental caries.⁷

FMR have been initiated in many preschool facilities, kindergartens, and elementary and junior high schools in Japan since the 1970s.⁸ Currently, a daily regimen of rinsing with 5 mL of 0.05% sodium fluoride solution is suitable for children younger than 4 to 6 years in preschool facilities and kindergartens, and a weekly regimen of rinsing with 7 to 10 mL of

* Corresponding author. Department of Oral Health and Welfare, Faculty of Dentistry & Graduate School of Medical and Dental Sciences, Niigata University, 2-5274, Gakkocho-dori, Chuo-ku, Niigata-shi, 951-8514, Japan.

E-mail address: yonezawa01@dent.niigata-u.ac.jp (D. Yonezawa).

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0.9% sodium fluoride solution is suitable for children in elementary and junior high schools; a duration of rinsing of more than 30 s, targeting 1 min, is implemented in Japan.⁹

In 2003, the Ministry of Health, Labor, and Welfare of Japan issued guidelines⁹ regarding fluoride mouth-rinsing. The guidelines recommend the use of a fluoride mouth rinse starting from the age of 4 years. In a national survey on the regional spread of programmes from preschool to junior high school during 2014 in Japan, 1,270,000 preschool children and schoolchildren were found to have participated in these programmes.¹⁰ In a study conducted in 1987, Tsutsui reported on the posttreatment effectiveness of FMR in preventing dental caries in permanent teeth; a 74% difference was found between students of a high school who had participated in a daily rinsing regimen since 4 years of age (in preschool facilities and elementary schools) and a weekly regimen since 12 years of age (in junior high schools) and students of other high schools who had not participated in any FMR.¹¹ In another study, FMR also showed a positive effect on the prevention of dental caries. The decayed, missing, and filled surfaces (DMFS) reduction rate for mandibular first molar occlusal caries in 12-year-old children was 17.3% for those in 1992 who started the programme at 6 years of age and 38.7% for those in 1993 who started the programme at 5 years of age.¹² These studies were conducted between the 1980s and 1990s, which was a time of high or moderate prevalence of dental caries in Japan.

However, national surveys by the Ministry of Health, Labor, and Welfare of Japan revealed a decreasing trend in the mean number of decayed, missing, and filled teeth (DMFT) from 1999 to 2016. For example, reductions in DMFT were 86.8% in children aged 10 to 14 years, 74.0% in those aged 15 to 19 years, and 57.4% in those aged 20 to 24 years.¹³ One possible reason for the reductions could be that the market share of fluoridated toothpaste was increased up to 91% at that time.¹⁴ Therefore, it is necessary to investigate whether the preventive effect of the preschool- and school-based FMR persists in the era of decreasing dental caries.

This study aimed to evaluate the posttreatment effect of an FMR on the prevalence of dental caries and the number of DMFS in newly enrolled university students.

Methods

Study population

This study was conducted as part of the regular dental health examination at Niigata University on students newly joining in May 2014 and 2015. The oral examination was performed on subjects in an area of the university campus set up for total health examination. We randomly recruited subjects from approximately 3000 new students aged between 18 and 25 years. Subjects were asked to complete permission papers and questionnaire forms. The questionnaire form included questions on demographic information, details of FMR, and information about dental health behaviours, including snack intake between meals, the frequency of tooth-brushing per day, use of interdental brushing and/or dental flossing aids, amount of toothpaste used on the toothbrush, and frequency of rinsing the mouth after tooth-brushing.

We obtained informed consent for this study from 597 university students. After the examination, we contacted the 1761 preschool facilities and elementary and junior high schools that the subjects had attended to identify the year of starting and/or discontinuing the FMR in each facility/school. If any of the restricted teeth of a subject were unerupted or the subject had a dental diagnosis of a condition, for example, orthodontic therapy, the subject was excluded from the analysis. Finally, 551 subjects were included in the analysis. The number of subjects who had not participated in any FMR was 364 (non-FMR group) and of those who had participated in FMR was 187 (FMR group). All 187 participants in the FMR group had participated in elementary school FMR; of these, 96 (51.3%) had only participated in an elementary school programme; 43 (23.0%) in elementary school and junior high school programmes; 22 (11.8%) in preschool facility and kindergarten, elementary school, and junior high school programmes; and 26 (13.9%) in preschool facility and kindergarten and elementary school programmes.

One dentist (author MY) examined the surfaces of the permanent teeth for dental caries by means of DMFS. A decayed tooth surface was recorded if any surface of the tooth had an unmistakable carious lesion or cavity, undermined enamel, or a detectably softened floor or wall. A missing tooth was one that had been extracted because of dental caries. A filled tooth surface was one with restoration but without cavities or dental caries. The equipment used in the examination included dental explorers to remove debris on the teeth surfaces, plane mouth mirrors, and a micro-head light with a 3-watt white light-emitting diode. No radiographic scanner or air compressor was used for the detection of dental caries.

Intra-examiner reliability

During the examination, the dentist who examined the teeth determined the consistency and intra-examiner reproducibility of the diagnostic criteria by examining a group of 24 subjects twice. The kappa value of reproducibility in the diagnosis of DMFS was 0.89 (almost perfect agreement).¹⁵

Statistical analysis

The mean DMFS and prevalence of dental caries in permanent teeth by sex, age, participation in FMR, and categories of data on dental health behaviours were calculated. To evaluate the preventive effect of FMR more closely, the status of dental caries in permanent teeth was evaluated separately for pits and fissure surfaces, proximal (medial and distal) surfaces, and free smooth (buccal and lingual) surfaces. Differences in the prevalence of dental caries in permanent teeth by category were evaluated using odds ratios with 95% confidence intervals (CIs), and statistical significance was determined using Fisher's exact test. The difference in the mean DMFS according to the categories was evaluated using the means of the mean values with their 95% CIs; statistical significance was assessed using Welch's *t* test for 2 groups, and Dunnett's method, as post hoc pairwise comparisons, was used to compare each treatment-/factor-level group of 3 or more than 3 groups to a reference group.

Table 1 – Caries prevalence and mean number of DMFS by demographic characteristics, fluoride mouth rinse (FMR), and dental health behaviours.

Variable	Category	N	Prevalence (%)	Odds ratio	95% CI			P ^a	Mean DMFS	95% CI			Difference ^b	P ^c
					Low	–	High			Low	–	High		
Sex	Male	259	56.8	1				4.05	3.19	–	4.91	ref.	n.s.	
	Female	292	63.7	1.34	0.95	–	1.88	3.71	3.10	–	4.32	–9.2%		
Age (years)	18.0	354	54.8	1				3.21	2.67	–	3.75	ref.		
	19.0	87	67.8	1.74	1.06	–	2.85	.029	3.95	2.76	–	5.15	18.7%	n.s.
	20.0	28	71.4	2.06	0.89	–	4.81	n.s.	4.43	2.25	–	6.61	27.5%	n.s.
	>20	82	73.2	2.25	1.32	–	3.83	.003	6.43	4.33	–	8.52	50.1%	.023
FMR at least in elementary school	No	364	64.6	1				.006	4.47	3.78	–	5.16	ref.	
	Yes	187	52.4	0.60	0.42	–	0.87		2.70	2.02	–	3.38	39.6%	<.001
Snack intake	No	38	50.0	1					1.79	0.83	–	2.75	ref.	
	Sometimes	419	60.9	1.56	0.80	–	3.03	n.s.	3.94	3.34	–	4.54	18.5%	.001
	Everyday	94	62.8	1.69	0.79	–	3.61	n.s.	4.38	3.03	–	5.74	26.7%	.007
Tooth-brushing frequency	Once/day	70	68.6	1					5.26	3.54	–	6.97	ref.	
	Twice/day	379	58.6	1.56	0.38	–	1.12	n.s.	3.75	3.13	–	4.38	14.4%	n.s.
	More than twice/day	102	61.8	1.69	0.39	–	1.41	n.s.	3.34	2.34	–	4.35	3.9%	n.s.
Use of interdental brushes	No	359	58.5	1					3.95	3.27	–	4.63	ref.	n.s.
	Yes	192	64.1	1.27	0.88	–	1.82	n.s.	3.72	2.96	–	4.48	5.8%	
Use of fluoride toothpaste	No	8	62.5	1					5.63	-0.11	–	11.36	ref.	n.s.
	Yes	543	60.4	0.92	0.22	–	3.87	n.s.	3.84	3.32	–	4.36	31.8%	

^a Fisher's exact test (2-tailed) comparing distributions of subjects with dental caries in permanent teeth.

^b Difference of mean values of DMFS between the reference (ref.) and the other categories.

^c Welch's t test (2-tailed) for 2 groups comparing mean DMFS between reference (ref.) and another category, and the Dunnett's method (2-tailed) for 3 or more than 3 groups comparing mean DMFS between the reference (ref.) and the other categories. CI, confidence interval; DMFS, decayed, missing, and filled surfaces; n.s., not statistically significant.

A multivariate logistic regression model was used to analyse the association between dichotomous variables (caries present or absent) as the dependent variable and the categories of demographic data, participation in FMR at least during elementary school, and dental health behaviours as the independent predictors.

P values $\leq .05$ were considered statistically significant. All statistical analyses were performed using SPSS 22.0 (IBM Corp.).

Ethical standards

The Committee on Study Involving Human Beings of Niigata University approved the ethical protocol of this study (Ethical No.25-R48-03-26), and written informed consent was obtained from the subjects. We have no conflicts of interest to declare.

Results

The prevalence of dental caries in permanent teeth and the mean DMFS according to sex, age, participation in FMR at least during elementary school, and categories of data on dental health behaviours are presented in Table 1. Differences in the prevalence of dental caries in permanent teeth between the subjects in the FMR group (51.3%) and those in the non-FMR group (64.5%) were statistically significant. There were 39.6% fewer DMFS amongst the subjects in the FMR at least during elementary school group. The mean DMFS and the prevalence of dental caries were positively correlated with age. The prevalence of dental caries in males was higher than that in females. Conversely, the mean DMFS

in males was lower than that in females. There was no statistical difference in the prevalence of dental caries and mean DMFS between both sexes. The mean DMFS was lower amongst subjects who responded “no” to questions on snack intake than amongst those who responded “sometimes” and “everyday.” There was no statistical difference in the prevalence of dental caries and mean DMFS amongst the other factors.

The prevalence of dental caries and mean DMFS in the FMR group, including subjects who participated only in the elementary school programme, were significantly lower than those in the non-FMR group. Although the other FMR group displayed a lower prevalence of dental caries and mean DMFS than the non-FMR group, there was no statistical significance (Table 2).

The mean DMFS with respect to the pits and fissures and the proximal and free smooth surfaces (buccal and lingual surfaces) are displayed in Table 3. The percentage reduction in DMFS was the highest for free smooth surfaces and the lowest for pits and fissures in the FMR and non-FMR groups; the percentage reduction in DMFS for the proximal surfaces was intermediate. The mean DMFS on free smooth-surface caries, proximal caries, and pits and fissure-surface caries were reduced by 57.3% (a difference of 0.43 surfaces per subject between the FMR and non-FMR groups), 48.4% (a difference of 0.60 surfaces per subject between the FMR and non-FMR groups), and 29.4% (a difference of 0.73 surfaces per subject between the FMR and non-FMR groups), respectively.

Multivariate logistic regression analyses demonstrated that the subjects in the FMR at least during elementary school group were protected against dental caries as compared to those in the non-FMR group. Age was identified as a risk

Table 2 – Caries prevalence and mean number of DMFS by period of FMR.

Period of FMR	N	Prevalence	Odds ratio	95% CI		P ^a	Mean DMFS	95% CI		Difference ^b	P ^c
				Low	High			Low	High		
Non-FMR group	364	64.6%	1				4.47	3.78	5.16	ref.	-
Elementary school	96	47.9%	1.97	1.25	3.11	.002	2.15	1.39	2.90	51.9%	<.001
Preschool and elementary school	22	59.1%	1.26	0.52	3.02	.383	2.86	0.96	4.77	36.0%	.659
Elementary and junior high school	43	55.8%	1.44	0.76	2.72	.172	3.93	1.86	6.00	12.1%	1.000
Preschool, elementary, and junior high school	26	57.7%	0.75	0.34	1.69	.310	2.58	0.90	4.25	42.3%	.316

^a Fisher's exact test (2-tailed) comparing distributions of subjects with dental caries in permanent teeth.

^b Difference: Difference of mean values of DMFS between the non-FMR group and the other FMR groups.

^c Welch's t test (2-tailed) comparing mean DMFS between the non-FMR group and the other FMR groups. CI, confidence interval; DMFS, decayed, missing, and filled surfaces; FMR, fluoride mouth rinse.

Table 3 – Comparison of the mean values of DMFS of the different tooth surfaces between FMR at least in elementary school and No FMR.

FMR	N	Pit and fissure surface				Proximal surface				Smooth surface			
		Mean	95% CI		P ^a	Mean	95% CI		P ^a	Mean	95% CI		P ^a
			Low	High			Low	High			Low	High	
No	364	2.48	2.18	2.77	.002	1.24	-0.94	1.55	.006	0.75	0.55	0.95	.001
Yes	187	1.75	1.38	2.11		0.64	0.34	0.94		0.32	0.17	0.47	
Difference (%) ^b		29.4				48.4				57.3			

^a Welch's t test (2-tailed) comparing mean DMFS between reference (ref.) and another category.

^b Difference of mean values of DMFS. CI, confidence interval; DMFS, decayed, missing, and filled surfaces; FMR, fluoride mouth rinse.

predictor of dental caries in adults. Although there was no statistical difference in the prevalence of dental caries and mean DMFS amongst males and females, sex was also identified as a risk predictor following multivariate logistic regression analysis. The other variables were not associated with dental caries (Table 4).

Discussion

In the present study, the posttreatment effects of FMR on dental caries in permanent teeth were apparent in Japanese university students aged between 18 and 25 years. Previous studies have also reported the preventive effects of FMR on

Table 4 – Standardised partial regression coefficients (β) and odds ratios in multivariate logistic regression analysis for predicting the prevalence of caries.

Independent variable	Category	β	Odds ratio	95% CI			P
				Low	High	High	
FMR at least in elementary school	No	0.12	1	0.40	-	0.84	.004
	Yes						
Sex	Male	0.11	1	1.10	-	2.50	.008
	Female						
Age (years)	18	0.16	1	0.99	-	2.78	n.s.
	19						
	20						
	More than 20						
Snack intake	No	0.04	1	0.29	-	1.44	n.s.
	Sometimes						
	Everyday						
Use of interdental brushes	No	0.05	1	0.59	-	1.53	n.s.
	Yes						
Use of fluoride toothpaste	No	0.00	1	0.24	-	4.48	n.s.
	Yes						
Tooth-brushing frequency	Once/day	-0.05	1	0.79	-	3.19	n.s.
	Twice/day						
	More than twice/day						

Dependent variable: Caries free 0, Caries 1.

CI, confidence interval; FMR, fluoride mouth rinse; n.s., not statistically significant.

Nagelkerke $R^2 = 0.078$.

dental caries in the permanent teeth of Japanese adults aged ≥ 20 years.¹⁶ The trend of increasing market share of fluoride toothpaste in Japan could have influenced the prevalence of dental caries in the permanent teeth of the subjects because age was found to be a statistically significant predictor of dental caries in the present study.¹⁷

Kishi et al.¹⁸ reported that 20-year-old Japanese adults who had participated in a daily 0.05% sodium FMR between 4 and 11 years of age and in a weekly 0.2% sodium FMR between 12 and 14 years of age presented with significantly lower caries than those who did not participate in such programmes (56%-71% difference in the mean DMFS). The former had fewer decayed tooth surfaces than the latter; the decay in the free smooth tooth surfaces especially was less than in the pits and fissures. These results in 20-year-old adults indicate that participation in FMR for 11 years between the ages of 4 and 14 years conferred posttreatment benefits.

In a study to evaluate the long-term caries-preventive effects of FMR, 637 subjects aged 20 to 39 years were divided into 4 groups: subjects who had participated in the programme from nursery to junior high school, those who had participated only in elementary school, those who had no experience of the programme, and others whose experience of the programme was unclear. Multiple regression analysis between the mean DMFT and the groups showed that those who participated in the programme from nursery to junior high school and those who participated only during elementary school had a negative association with the mean DMFT.¹⁶

In the present study, however, it was difficult to assess the preventive effect of preschool FMR because the programme timelines amongst the subjects were complicated. Whilst the World Health Organisation has emphasised that fluoride mouth rinse is to be avoided in children younger than 6 years due to the risk of dental fluorosis resulting from daily ingestion of a certain amount of fluoride,⁶ the guidelines from the Ministry of Health, Labor, and Welfare of Japan recommend the use of a fluoride mouth rinse from the age of 4 years.¹⁰ The present study failed to ascertain that the caries-preventive effects of FMR started at preschool were better than those of FMR started at elementary school; the benefits of the FMR started at preschool seemed to have disappeared. The association between age and dental caries in terms of the DMFS score was found to be statistically significant in this study, which is inevitable because dental caries is an irreversible and progressive disease. Ohara et al.¹² reported that the introduction of FMR had a positive effect on the prevention of dental caries based on the DMFS rates of the first mandibular molars of 12-year-old children. Greater differences in caries rates may be attributed to the age at the initial fluoride mouth rinse; 85% of the mandibular first molars would benefit from the fluoride immediately after eruption if the mouth rinse was started at 5 years, whilst only 25% of the molars would benefit if the rinse was started at 6 years. Besides, because fluorine is not available from general intake routes, such as fluoridated water, tablets, and foods, in Japan, dental fluorosis is not expected to be a problem.^{7,19-20} Multiple regression analysis based on data from 1737 sixth graders in elementary schools comprising 67,672 schoolchildren obtained from the Dental Health Database of Niigata Prefecture, Japan, indicated that FMR in preschool facilities, kindergartens, and

elementary schools were statistically significant variables.²¹ Therefore, to prevent dental caries in the pit and fissure surfaces, especially of the first molars, it is recommended to start the FMR for children younger than 6 years.

Caries reduction by FMR at least during elementary school on different tooth surfaces indicates a more detailed impact of programme participation on the dental needs of adults. In this study, the free smooth surfaces had the highest percentage reduction in DMFS. Dirks²² pointed out that the repair of cavities in these surfaces seems relatively simple, but the durability of these restorations is much lower than those of fissure fillings. Moreover, there is a great danger to the integrity of the tooth and surrounding tissues. The percentage reduction in DMFS on proximal surfaces was intermediate, and their repair is more time-consuming than that of other types of fillings.²² The percentage reduction in DMFS was the lowest in the pit and fissure surfaces; dental caries on these surfaces tend to develop soon after the tooth erupts and progress rapidly. If dental caries in the pit and fissure surfaces remain incipient because of the programme, a preventive fissure sealant is applied instead of an operative treatment with filling materials.²³ The percentage reduction in the DMFS in the pit and fissure surfaces was the lowest, a 27.9-point difference compared to that for the free smooth surface. Comparing the mean values, the difference in reduction was 0.30 for surfaces and 41.1% for the mean DMFS. The benefit of fluoride was the lowest for the pit and fissure surfaces.

This study has a few limitations. First, it is observational and not experimental. Neither the subjects nor the preschool facilities, kindergartens, and elementary and junior high schools were randomly assigned to receive the programme. Second, although data on the FMR and individual use of fluoride-containing toothpastes were obtained, exposure to other sources of fluoride, such as fluoride in drinking water—which is uncommon in Japan—and topical application of fluoride in dental clinics, was unknown. Third, the programme timelines were complex; some children might have had only limited exposure to the programme because of the mobility of their families. This could likely contribute to the weakening of the preventive effect of the programme. In this study, it was impossible to obtain data regarding the socioeconomic inequalities amongst the subjects. However, all subjects belonged to the same university; thus, their educational and socioeconomic backgrounds during childhood were considered comparable. Finally, selection bias could limit the scope of our findings.

Indeed, participation in FMR at least during elementary school is not likely the most important preventive measure for the reduction of dental caries in adults, as FMR may only relate to a caries-preventive effect at the time. The subjects' continuous fluoride exposure for their entire lives, such as using fluoride toothpaste with appropriate tooth-brushing as individual health practice, possibly through water fluoridation as a public health measure if it becomes feasible, and the other methods of delivering fluoride for the prevention of dental caries is inevitable.

In this study, FMR showed a significant benefit in caries prevention despite the decline in the prevalence of caries and increase in the use of fluoridated toothpaste. Moreover, although the effectiveness of decay prevention varied according to the tooth surface, the overall reduction in caries renders

the FMR beneficial. Multivariate analysis indicated that participation in FMR at least during elementary school, age and sex are statistically significant predictors for the reduction in the prevalence of dental caries in the permanent teeth.

Participation in an FMR at least during elementary school is a predictor for reduction in the prevalence of dental caries in permanent teeth in adults after investigating the posttreatment effects of FMR retrospectively and after adjustment for some confounding factors.

Author contributions

DY generated data and wrote the manuscript. MY planned the study and wrote the manuscript.

Conflict of interest

None disclosed.

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