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Community effectiveness of fissure sealants and the effect of fluoridated water consumption

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Objectives: This study investigated the effectiveness of fissure sealants in a community-based programme and the relationship between fissure sealants effectiveness and exposure to fluoridated water. ***Design:*** Prospective cohort study of children attending the School Dental Service (SDS) of two Australian states, Queensland and South Australia, across a period of between 6 months and 3.5 years (mean=2 years). ***Methods:*** Oral health data on 4–15-year-olds were obtained as part of regular examinations by the SDS while questionnaire data on residential and water consumption history were provided by children's parents or guardians. ***Participants:*** A sub-group of 789 children (mean age=10.5 years) was selected with one contralateral pair of permanent first molars at baseline where the occlusal surface of one molar had been fissure sealed while the paired surface was diagnosed as sound. ***Results:*** The caries incidence of the fissure sealed occlusal surfaces was 5.6% compared to 11.1% for sound surfaces ($p<0.001$), demonstrating a 50% reduction in caries incidence for sealed vs non-sealed surfaces. The reduction in caries increment attributable to fissure sealing increased across fluoridated water exposure categories - a 36.4% reduction was found for children with 0% exposure ($p>0.05$), a 55.0% reduction for children with intermediate exposure ($p<0.01$), and an 82.4% reduction for children with 100% lifetime exposure to fluoridated water ($p<0.001$). Differences between odds ratios for fissure sealants across exposure categories were not statistically significant. *Conclusions:* The effectiveness of fissure sealants in community-based programmes may be further improved when coupled with increased lifetime exposure to optimally fluoridated water.

Key words: Caries; children, fissure sealants; water fluoridation

Introduction

Fissure sealants have been demonstrated to be efficacious in the prevention of caries. Originally the effectiveness of fissure sealants was assessed using a split-mouth methodology, where children with pairs of sound first molars were selected and subsequently had one randomly selected molar sealed while the other molar was left unsealed to serve as a passive control. A meta-analysis of 44 such studies by Llodra *et al.* (1993) found that the percentage of decay prevented by a one-time sealant application was 58.6% at 48-months. Similarly, Weintraub (1989) evaluated 20 studies that examined the percent effectiveness of sealants and found the medians for effectiveness to range from 83% after one year to 55% after seven years. These randomised clinical trials used children with both low and high caries risk and from fluoridated and non-fluoridated areas.

Following the acceptance of fissure sealants as an effective caries preventive measure in the mid 1970s, it became unethical to use homologous paired teeth as non-treated controls (Simonsen, 1980). Subsequent studies mainly focussed, therefore, on other outcomes. The benchmarks for effectiveness became sealant retention, the effectiveness of sealants in arresting existing decay, and differential effectiveness of different sealant types. While it has been argued that sealants are 100% effective in preventing pit and fissure caries if completely retained (Kumar and Siegel, 1998), retention rates have been found to vary from one study to the next. Retention rates are generally higher in clinical studies than in public sector programmes where multiple clinicians are employed. However, some public programmes have shown high sealant retention. In a programme in Manitoba, Cooney and Hardwick (1994) found 85% complete retention after two years. Similarly, in Saskatchewan, an evaluation of a publicly funded dental insurance programme found a retention rate of approximately 80% over a three-year period (Ismail *et al.,* 1989).

In Australia, the school dental service, which provides free or reduced-cost service to primary and secondary school children, has recently increased the use of pit and fissure sealants. Although there is preferential targeting of sealants towards children with some caries experience, even in children without caries experience the percentage receiving fissure sealants has increased, for example, from 10.9% of 12-year-olds in 1989 to 28.0% of 12-year-olds in 1999 (Armfield *et al.,* 2003). In comparison, 39.2% of 12-year-old Australian children in 1999 with previous caries experience had at least one fissure sealant. The number of fissure sealants per child has also increased rapidly and for 12-year-olds in 1999 was just under one per child on average (Armfield *et al.,* 2003).

Changes in the epidemiology of dental caries towards the end of the 20th century can be seen as enhancing rather than detracting from the rationale for sealant

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usage (Adair, 2003). There is now considerable evidence that the bulk of caries increment in children in Western countries is attributable to pit and fissure caries, with caries development in proximal surfaces being relatively low (Li *et al.,* 1993; Slade *et al.,* 1996). In the permanent dentition of children, caries experience is confined increasingly to occlusal surfaces of molar teeth (Chestnutt *et al.,* 1996). This altered disease distribution coupled with a continuing effort to further reduce caries experience has increased the applicability of pit and fissure sealants as an appropriate preventive measure.

Nonetheless, the ever-increasing cost of large-scale pit and fissure sealant programmes in Australia again necessitates the need for research into their effectiveness in reducing caries experience. Of particular significance are changing disease patterns which must also be taken into account when assessing sealant efficacy. Since 1977, for example, the number of decayed, missing and filled teeth (DMFT) in Australian 12-year-olds declined from 4.79 (Commonwealth Department of Health, 1987) to 0.83 in 1999 (Armfield *et al.,* 2003). In 1999 approximately 65% of 12-year-olds had no caries experience in their permanent dentition. Low caries experience has led some researchers to conclude that it is inefficient to apply dental sealants to sound pit and fissure surfaces as these surfaces are unlikely to become decayed (Heller *et al.,* 1995).

Changes in caries prevalence pose a critical issue for the analysis of the effectiveness of fissure sealants. One development underpinning the decline in caries experience has been the widespread and increasing exposure of children to fluorides from professional applications, discretionary sources such as toothpaste, and fluoridated water supplies. However, early studies on the community effectiveness of fissure sealants often took place in both low-fluoride exposure and high-caries environments. Since the cessation of studies employing half-mouth designs, caries experience has declined appreciably in many industrialised countries, including Australia. Therefore, there is a need for the evaluation of the effectiveness of sealants against this current background of extensive fluoride exposure and the considerable reduction in caries experience that has taken place.

A further issue to be addressed when measuring sealant effectiveness is the potential differential effectiveness of pit and fissure sealants across different levels of exposure to fluoride. One might, for example, expect fissure sealants to be most effective for children with the least exposure to the preventive benefits of fluoride, given that these children are effectively more 'at risk' of dental caries. For the current study the potential benefit of exposure to optimally fluoridated water was investigated. Over 50 years of evidence testifies to the caries-preventive effect of the consumption of fluoridated water, with children without exposure to fluoridated water generally having more caries. However, there are no studies that bear directly on the relationship between the preventive benefits of sealants and those of exposure to fluoridated water in the reduction of caries. Considering the importance of both these approaches to caries prevention, such a study is well overdue.

This study's aims were to examine the effectiveness of fissure sealants in preventing caries and to investigate the differential effectiveness of fissure sealants across categories of exposure to fluoridated water.

Method

Participants and sampling protocol

This study used a multi-site cohort of children, with baseline oral health data collected between July 1991 and June 1992, and longitudinal follow-up data collected prospectively from between 6 months and 3½ years post-baseline. Children were randomly selected according to birth date from the population of patients attending for dental examinations with the school dental service (SDS) in two Australian states, Queensland and South Australia. They were provided with a questionnaire to take home and be completed by their parent or guardian.

The SDS provides routine dental care to children whose parents consent to their enrolment in the service. Routine dental care involved regular examinations occurring approximately yearly at the time of data collection, as well as preventive services, restorations and oral surgery as required. In 1991/92, over 80% of preschool and primary school children and approximately 70% among secondary school students in South Australia (secondary school children were not covered by the SDS in Queensland) were enrolled in the SDS.

Children were randomly sampled from two strata in each state. In South Australia, one stratum was fluoridated, Adelaide, the state capital, where approximately 1 in 12 patients were selected (those born on the 13th, 30th or 31st day of any month). In 1992 the estimated resident population (ERP) of 5–15-year-olds in Adelaide was 139,018. The other stratum comprised South Australia rest-of-state (which was mixed in terms of fluoridated water status), where children were selected if their day of birth fell on the 13th or between the 26th and 31st day inclusive of any month, giving a sampling ratio of approximately 1 in 5. Outside of the capital, South Australia is predominantly non-fluoridated and the ERP of 5–15-year-olds in 1992 was 61,763. In Queensland, children aged 5 to 12 years inclusive were sampled in two strata. One stratum was Brisbane (the non-fluoridated state capital) where a sampling ratio of 1:5 was achieved by selecting children with birthdays between the 1st and 6th day of any month. The other stratum was Townsville (a rural city, fluoridated 1965) where all children were sampled. In 1992 the 5–15-year-old ERP in Brisbane was 201,084 and in Townsville was 61,763.

The sampling scheme was designed to provide for approximately equal numbers of children at each of the four sites and the 5–15-year-old age group was used for these calculations because population figures available from the Australian Bureau of Statistics only provided for specific age range groupings (5–9, 10–14) by Statistical Divisions, not individual age year statistics. Sampled age ranges for both states were based on the ages of the population served by the school dental services in that state.

Study design

This investigation employed an observational split mouth study design. Children were selected who had one site within their mouth that had received the treatment, in this case a fissure sealant, while the contralateral site was untreated and served as the control. No information was available on who had placed the sealant or how long the sealant had been in place prior to participation in the study. Inclusion criteria were that a child must have one contralateral pair of permanent first molars at baseline where the occlusal surface of one molar had been fissure sealed while the paired surface was diagnosed as sound. Designation of sites to sound or fissure sealed was observed, rather than randomly assigned as used traditionally in clinical split mouth trials. While the contralateral molars could be from either arch, to avoid problems due to clustering, where children had differing contralateral pairs in both arches, analyses were carried out on molars in the maxilla arch only. Each surface pair, therefore, represents one child.

Dental examination

Data describing caries experience were recorded by either dental therapists or dentists from the School Dental Service during the course of scheduled periodic examinations. In South Australia and Queensland dental therapists are qualified to examine and diagnose, and provide restorative and preventive dental services for children under the supervision of a dentist. Written instructions were supplied to clinical staff concerning criteria for recording the decayed, missing and filled indices on deciduous (dmfs) and permanent tooth surfaces (DMFS). The instructions made use of visual criteria only, using the approach advocated by the World Health Organization (1987) with further guidelines for their surface level application from the US National Institute of Dental Research (1989). The scoring of decay was based on visual criteria and was recorded if cavitation had occurred and/or the lesion extended into the dentine. All surfaces of teeth missing due to decay were recorded in dmfs and DMFS scores. Written guidelines were discussed during in-service training and other staff meetings. Due to the large number of examiners and their widespread geographical distribution across the two states, there were no additional calibration procedures. However, the design aspects employed in this study were deemed consistent with the orientation of the project towards community effectiveness using a practitioner perspective on the diagnosis of disease experience.

Questionnaire

At the time of a child's visit to a SDS clinic during the baseline enrolment period, a self-complete questionnaire was provided to each sampled child to be given to his or her parent/guardian. Up to two reminder notices were mailed to parents/guardians who did not respond to the questionnaire. Efforts were made to obtain missing questionnaire data and to correct erroneous information by telephoning the participant's parents/guardians. Up to six attempts were made to contact the parents and approaches were made at different times of the day.

The parental questionnaire was used to obtain information on lifetime residential history, usual source of drinking water and other information such as socioeconomic status and oral health behaviours. Parents/guardians were asked to specify the location of each residence that their child had lived at for greater than six months, the length of time at each residence and the usual source of drinking water at each residence ('Public Supply', 'Tank/Other', or 'Don't Know'). Postcode information was matched with an electronic database containing the fluoride content of water for each postcode within Australia, which was derived from a variety of health and water authorities. For children who had resided for at least six months in countries outside Australia, fluoridation status was obtained where necessary from various authorities from those countries or from reported assays of local water content. Due to variations in the precision with which fluoride concentrations were specified, fluoride content was categorised as being negligible or 0 ppm (less than 0.3 ppm F), sub-optimal or 0.5 ppm (0.3 to 0.7 ppm F), or optimal or 1 ppm (greater than 0.7 ppm F). For each residence the time spent at that residence was multiplied by the categorised fluoride content of the public water supply for that area. Lifetime consumption of fluoridated water was calculated by summing, across all residences, time spent at each residence where fluoridated mains water was the usual source of drinking water. This was then divided by the child's age to obtain a measure ranging from zero (no consumption of fluoridated tap water) to 100% (all of lifetime consumption of fluoridated tap water). For the purposes of this study, children were classified as having had no consumption of fluoridated water, 100% consumption of optimally fluoridated water, or intermediate consumption (1%–99%).

Outcome measures and analyses

Descriptive statistics were used to compare characteristics of the study sample with that of the entire sample from which the sub-group of cases were drawn. McNemar's test (McNemar, 1947) was used to test whether caries incidence differed significantly between test and control sites. McNemar's test has been recommended by Riordan and FitzGerald (1994) as suited to a split mouth trial, and uses paired proportions where non-tied pairs only are used and tied pairs do not contribute to the difference between test and control. As an alternative, a paired samples t-test of Crude Caries Increment (CCI) was also used between the test and control sites. Whereas incidence measures changes in the probability of disease risk over time, increment is a measure of the change in the extent of disease across multiple points in time.

Univariate analysis of variance was used to test for differences in demographic, oral health status and behaviour characteristics across fluoridated water consumption groups. Chi-squared tests were performed to test for significant differences in other demographic and socio-economic characteristics across fluoridated water consumption groups.

Sealant effectiveness was evaluated by two measures. Percent effectiveness has traditionally been the most widely used and compares the caries incidence of sealed sites with that of unsealed, or 'control' sites. Percent effectiveness is equal to the number of new carious ‘control’ sites minus the number of new carious sealed sites divided by the number of new carious ‘control’ sites and then multiplied by 100 to obtain a percentage. The other measure, net gain, relates the difference between caries incidence in the control versus the sealed sites in terms of the total number of surface pairs in the study. As such, net gain can be seen as an indicator of the number of sites ‘saved’ from caries per 100 sites treated. Net gain is equal to the number of carious ‘control’ sites minus the number of carious sealed sites divided by the total number of tooth pairs and then multiplied by 100. Finally, odds ratios and 95 percent confidence intervals for the odds ratios were calculated for the onset of new disease across each of the fluoridated water consumption categories.

Results

There were 18,348 children sampled for the study from Queensland and 13,911 from South Australia. Questionnaire data were obtained from 10,827 children from Queensland (59.0%) and 9,988 children from South Australia (71.8%) and these were matched with the baseline and follow-up clinical data obtained from the school dental services. The results for a sub-group of 1,077 children from the study population were selected who met the criteria for this study of having an occlusal surface of one molar fissure sealed and a sound occlusal surface of the contralateral tooth. Of these children, 114 (10.6%) had sealed/non-sealed matching teeth in both their upper and lower arch. Approximately 49% of all matched pairs were in the upper arch and 51% in the lower arch. Cases where the sound surfaces were fissure sealed prior to follow-up, and two cases where the surfaces were recorded at follow-up as unerupted or missing due to reason other than caries, were removed, leaving a total of 789 children.

A comparison of demographic, socio-economic and oral health behaviours of the entire sample and the sub-sample used in this study is provided in Table 1. The only substantial difference was in relation to the age of children, with the study sample comprising a higher percentage of older children than the entire sample. The mean age of the children at baseline was 10.4 years and the mean time to follow-up was 2.01 years. Table 2 shows the changes in surface status between baseline and follow-up, after excluding cases where initially sound surfaces became fissure sealed or were recorded as unerupted or missing. Almost 89% of cases that were sound at baseline were sound at follow-up, while 7.6%

Table 1. Distribution of demographic, socio-economic and oral health behaviour characteristics for the entire sample and study sample

Characteristic	*Entire sample (n=20,815)*		*Study sample (n=789)*	
	n	*%*	*n*	*%*
Gender				
Male	10,441	51.2	396	50.2
Female	9,968	48.8	393	49.8
Age				
4-6	4,535	21.8	9	1.1
7-9	7,655	36.8	271	34.3
10-12	6,492	31.2	351	44.5
13-15	2,075	10.0	158	20.0
Income				
Up to $20,000	4,643	24.3	181	25.2
$20,001 to $30,000	4,758	24.9	184	25.6
$30,001 to $40,000	4,268	22.3	153	21.3
$40,001 to $50,000	2,420	12.6	85	11.8
More than $50,000	3,048	15.9	115	16.0
Education				
Not completed secondary	5,692	28.2	251	32.6
Completed secondary	7,161	35.4	283	36.8
Some university/college	2,413	11.9	81	10.5
Completed university/college	4,945	24.5	154	20.0
Brushing frequency				
Less than once per day	1,223	5.9	67	8.6
Once per day	5,820	28.4	239	30.8
More than once per day	13,414	65.6	469	60.5
Past or current use of fluoride drops or tablets				
Yes	4,333	20.8	203	25.9
No	16,014	76.9	566	72.2
Don’t know	306	1.5	15	1.9

Table 2. Surface changes from baseline to follow-up

	Baseline status			
Follow-up status	*Initially sound*		*Initially fissure sealed*	
	n	%	*n*	%
Unerupted	0	0.0	0	0.0
Sound	701	88.8	295	37.4
Missing (other)	0	0.0	0	0.0
Fissure sealed	0	0.0	450	57.0
Filled	60	7.6	29	3.7
Decayed	28	3.5	15	1.9
Total	789	100.0	789	100.0

of cases were filled and 3.5% decayed at the end of the study period. Only 57% of surfaces that were fissure sealed at baseline remained sound and fissure sealed at follow-up, with 37.4% of surfaces reverting to sound only, and 5.6% becoming decayed or filled.

To test whether caries incidence differs significantly between test and control sites in a split mouth trial, McNemar's test is used. According to this inferential test, the difference between test and control sites was significant, McNemar's $\chi^2 = 18.98$, $p<0.001$

The mean crude caries increment (CCI) for initially sound occlusal surfaces was 0.11, which was almost double the caries increment for surfaces that were fissure sealed at baseline (CCI = 0.06). Using a paired samples t-test, this difference was found to be statistically significant, $t(789) = 4.41$, $p<0.001$.

Using the outcome measures of percent effectiveness and net gain, this study found the effectiveness of fissure sealants in comparison to the control surfaces to be 50%. Eighty-eight of the sound occlusal surfaces became carious in comparison to 44 of the contralateral fissure sealed surfaces, meaning that the fissure sealants reduced caries increment by one half. The net gain of using fissure sealants was 5.6, indicating the number of surfaces "saved" from caries per 100 surfaces treated.

Results were further analysed by lifetime consumption of fluoridated water. Sealant retention rates across the 0%, 1-99% and 100% fluoride exposure groups were 50.7%, 70.7% and 57.3% respectively. Other differences between the three exposure groups in terms of demographic, socio-economic and oral health behaviour characteristics are provided in Tables 3 and 4. Differences between the groups occurred in mean age, baseline full mouth DMFS and resident location. Children with intermediate lifetime consumption of fluoridated water were older and had a higher baseline DMFS score than did children in the other two exposure categories, while a significantly higher percentage of children in the 100% exposure category resided in a metropolitan location compared to the other children.

The percent effectiveness and net gain of fissure sealants can be seen to increase with increasing lifetime consumption of fluoridated water (Table 5). Percent effectiveness was 36.4% for children with 0% lifetime consumption, 55.0% for children with intermediate lifetime consumption, and 82.4% for children with 100% lifetime consumption of optimally fluoridated water. Across fluoridated water consumption categories, net gain increased from 3.81 to 5.23 to 8.92. The odds of fissure sealed occlusal surfaces compared to sound surfaces becoming carious across the study period also decreased systematically as lifetime consumption of fluoridated water increased. However, the odds ratios did not differ significantly from each other.

Discussion

Even in a community setting, against a backdrop of low caries levels and high exposure to discretionary fluorides, fissure sealants were found to be effective in reducing caries increment. In addition, fissure sealants were found to be most effective for children with greater consumption of optimally fluoridated water.

This study used a split mouth design, which is particularly suitable for testing the effectiveness of fissure sealants because the sites are subjected to almost identical oral environments. In this way, the split mouth design neatly avoids a number of potentially confounding factors, particularly those due to differences in diet, oral hygiene behaviours and exposure to preventive regimens (Riordan and FitzGerald, 1994). The use of the split mouth design therefore disqualifies a number of possible confounders as being the actual cause for the demonstrated effectiveness of sealants.

Although not statistically significant, the finding that fissure sealants tended to be more effective for children who consumed a higher lifetime percentage of fluoridated water is unexpected and at odds with arguments that fissure sealants are best targeted towards child populations at high risk (Simonsen, 2002) and that populations having higher levels of caries attack will show more favourable results for fissure sealant effectiveness (Kumar and Siegel, 1998). Although Weintraub (1989) has argued that the median effectiveness of fissure sealants appears to be better for fluoridated communities than for non-fluoridated communities after one or two years, this finding is based on a limited number of reviewed studies and discrepant results were found in studies over a two year time period.

It is possible that confounding may be responsible for the results obtained in this study, with children in the exposure categories differing on some key characteristic that is also related to fissure sealant effectiveness. However, no consistent relationship was found between numerous demographic, socio-economic and oral health behaviour characteristics and fluoridated water exposure

Table 3. Distribution of demographic and oral health status and behaviour characteristics by lifetime consumption of fluoridated water

Characteristic	*Lifetime consumption of fluoridated water*					
	0%		*1–99%*		*100%*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age***	9.66	1.94	10.94	2.14	10.29	2.05
Mean period of follow-up	1.95	0.76	2.00	0.77	2.13	0.84
Full mouth DMFS at baseline**	0.41	0.88	0.72	1.28	0.61	1.14
Full mouth DMFS at follow-up	1.09	1.74	1.20	1.73	1.04	1.54
Rest-of-mouth CCI†	0.61	1.25	0.53	1.08	0.45	0.92
Brushing frequency per week	10.75	4.26	11.07	4.50	10.92	4.04
Months using fluoride tablets	46.35	33.15	39.12	32.07	55.33	55.00

†Crude Caries Increment excluding paired study and control occlusal surfaces
Analysis of Variance: ** $p<0.01$, *** $p<0.001$

Table 4. Distribution of demographic and socio-economic characteristics by lifetime consumption of fluoridated water

Characteristic	*Lifetime consumption of fluoridated water*					
	0%		*1–99%*		*100%*	
	n	*%*	*n*	*%*	*n*	*%*
Gender						
Male	109	52.2	205	48.8	81	51.6
Female	100	47.8	215	51.2	76	48.4
Income						
Up to $20,000	45	23.9	104	27.0	30	21.1
$20,001 to $30,000	55	29.3	97	25.2	32	22.5
$30,001 to $40,000	40	21.3	78	20.3	34	23.9
$40,001 to $50,000	25	13.3	41	10.6	19	13.4
More than $50,000	23	12.2	65	16.9	27	19.0
Education						
Not completed secondary	64	31.4	129	31.5	56	36.8
Completed secondary	81	39.7	149	36.3	53	34.9
Some university/college	19	9.3	55	13.4	7	4.6
Completed university/college	40	19.6	77	18.8	36	23.7
*Resident location****						
Metropolitan	129	61.7	188	44.8	152	96.8
Rural or remote	80	38.3	232	55.2	5	3.2

Chi-Squared: *** $p<0.001$

Table 5. Percent effectiveness, net gain and odds ratios of fissure sealants by lifetime consumption of fluoridated water

Lifetime consumption of fluoridated water	*n*	*Sound to decayed (%)*	*Sealed to decay (%)*	*Percent effective-ness (%)*	*Net gain*	*Odds ratio*	*95% confidence intervals*	
							Lower	*Upper*
0%	210	10.5	6.7	36.4	3.81	0.61	0.31	1.23
1–99%	421	11.7	6.4	55.0	5.23	0.52	0.32	0.85
100%	157	10.8	1.9	82.4	8.92	0.16	0.05	0.56

categories. Although children within exposure categories differed significantly by age, location and DMFS at baseline, the relationship between consumption of fluoridated water and these variables was not of a linear type. In addition, while it might appear that children with 100% lifetime consumption of fluoridated water are more 'at risk' than children with 0% lifetime consumption given the significant difference in baseline DMFS, this difference is likely to be related to differences in the age of the two groups. Finally, while the months spent using fluoride tablets appears high for children with 100% lifetime consumption of fluoridated water, only 9 (5.7%) of the 157 children from fluoridated areas actually used fluoride tablets or drops at any time. It is therefore unlikely that the additional benefit of exposure to discretionary fluoride from tablets or drops is responsible for the apparent increase in effectiveness of fissure sealants in areas with water fluoridation.

It should be noted that although not statistically significant, a 50% difference did exist between the rest-of-mouth CCI of children in the 0% lifetime consumption group compared to the 100% lifetime consumption group. This implies differences in underlying disease activity, presumably due in large measure to fluoride exposure but possibly also influenced by the use of fissure sealants and differentials in their efficacy.

It might be argued that exposure to fluoride changes the form or structure of the enamel, altering the physical retention of the sealant or the acid etching process. Again, however, there is no linear relationship between fluoride exposure groups and sealant retention with higher retention for the middle exposure group than for the 0% or 100% fluoride exposure groups. More research is therefore required both to confirm the interaction found here between fissure sealant effectiveness and consumption of fluoridated water and to provide an explanation for this relationship.

There are several limitations to this study. First, the issue of sealant retention was not investigated and this has implications for the interpretation of the results presented here. Numerous studies document that caries increment in initially fissure sealed teeth is related to the continued retention of the sealant. While international studies have found sealant retention rates to vary from about 40% after 6–7 years (Heidmann *et al.,* 1990) up to 80% after 8 years (Wendt and Koch, 1988), an Australian study found complete retention rates over a period of 2–3 years of between only 52% and 54% for mandibular and maxillary molar sealants respectively (Messer *et al.,* 1997). The findings in the current study that only a third of sealants were not retained to follow-up compares favourably with these results. While retention rates appear adequate, it is quite likely that sealant effectiveness could be further increased if retention could be improved or if sealants were replaced when lost.

Due to the design of the study there was no opportunity to quantify examiner reliability. This might have resulted in the introduction of error variance into the results due to variations in the classification of disease experience and identification of fissure sealants. However, it is unlikely that the lack of calibration introduced any systematic bias into the results. Fluoride exposure, for instance, was determined from detailed questionnaire material provided by parents, to which dental examiners were not privy. In addition, participation in the study was not confirmed until after the dental examinations took place and the questionnaire was completed and returned by a child's parent.

Another issue not addressed in this study is the reason for the initial differential sealing of the contralateral first molars. Based on the likelihood that sealant placement is related to perceived risk, it is possible that the fissure sealed surfaces in this study were assessed as more 'at risk' than the contralateral molar. The results of this study could, therefore, be an underestimation of the actual effectiveness of fissure sealants in preventing caries increment. However, it is also possible and indeed quite likely that some of the initially sound paired teeth in this study had been previously fissure sealed but had failed to retain the sealant. If these teeth were initially considered to be at high risk of developing caries the findings in terms of effectiveness may represent an overestimation of effect. It is not possible from the data to examine this hypothesis but it should be noted that at the time the study was initiated between 40% and 50% of 10–15-year-old children with no caries experience had received fissure sealants, so it was not the case that only high-risk children received fissure sealants.

While this study limited itself to an investigation of effectiveness, the results have potential application to economic considerations of fissure sealant usage. A number of studies have attempted to assess the cost effectiveness of sealant programmes in community or school-based settings within the context of relatively low caries experience in children. While some studies have found economic efficiencies only in the targeting of high-risk children (Klein *et al.,* 1985) or for the sealing of incipient lesions (Heller *et al.,* 1995), other studies have found preventive programmes incorporating fissure sealants to be both efficacious and cost effective (Morgan *et al.,* 1998). In his review of the economic analyses of pit and fissure sealants, Deery (1999) concludes that although recent studies support the efficiency and effectiveness of fissure sealants, many studies are flawed or contain serious limitations. In general, the literature relating to the economic evaluation of sealants is seen as inconclusive and containing contradictory findings. He argues that there is a need for well-designed studies utilising data from 'real world' situations, rather than extrapolation from clinical trials, and that this should involve examining modern materials in populations with current caries prevalence. Therefore, the quantification of the effectiveness and net gain of fissure sealants in the reduction of caries incidence demonstrated in this study, when combined with service provision data, may allow for an accurate assessment of the cost-effectiveness of fissure sealants in low-caries, high discretionary fluoride exposure regions characterising most of Australia.

In conclusion, this study found not only that fissure sealants are still effective even in a contemporary high-fluoride exposure, low caries environment, but that the extent of its effectiveness varies according to the level of consumption of fluoridated water. The observed effectiveness of fissure sealants in community-based programmes may be further improved when coupled with increased lifetime consumption of optimally fluoridated water.

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