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An Assessment of the Changes in the Prevalence of Dental Caries Over Time in Three Different Locations in NSW, Australia

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Abstract

Objective: To monitor changes in dental caries prevalence of 10-13 year old children living in a fluoridated area, a newly fluoridated area and an area without water fluoridation in NSW, Australia.

Method: Dental caries prevalence was recorded for 10-13 year old children living in three locations in NSW by six trained and calibrated examiners for the years 2009 and 2011. Caries experience was measured using the dmft and DMFT indices, the percent caries free and the Significant Caries Index. Multivariate analysis of the presence of caries (DMFT and dmft) was also conducted. A questionnaire recorded demographic data, tooth brushing behavior and sugary drink consumption which could be confounders. Univariate analysis was undertaken to determine independent predictions of dental caries.

Results: The caries prevalence changed over time. In 2009 the mean dmft and DMFT scores were 0.40 and 0.48 respectively for the fluoridated area, 0.68 and 0.59 for the newly fluoridated area and 0.74 and 0.99 for the non- fluoridated control area. In 2011 the mean dmft and DMFT scores were 0.32 and 0.38 for the fluoridated area; 0.44 and 0.45 for the newly fluoridated area; and 0.67 and 0.71 for the non- fluoridated area respectively. The multivariate analysis confirmed the statistical significance of these findings.

The modeling indicated that brushing twice per day reduces caries, and that water fluoridation appears to be a superior factor for reducing the number of children with caries. In 2009 and 2011, the proportion of children brushing their teeth twice per day was 76-78% in the non-fluoridated region, a constant 69% in the newly Fluoridated region but only 55-60% in the established Fluoridated region. A synchronous improvement in the proportion of caries-free

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children in the Fluoridated region was observed (61% in 2009, 68% in 2011), as was an even larger improvement in the newly Fluoridated region (50% in 2009, 61% in 2011). In contrast, the non-fluoridated region presented similar proportion of caries-free children for both years (49% in 2009 vs 52% in 2011).

So despite having the best tooth brushing behaviour, the non- fluoridated population has the smallest proportion of caries-free children.

Conclusion: Those children living in the fluoridated areas had a lower prevalence of dental caries than those who did not have access to this public health measure.

Introduction

Dental caries is a major public health problem, and most children have experienced caries in their primary and permanent teeth [1]. In order to reduce the impact of dental caries the state of New South Wales (NSW) implemented a water fluoridation program in 1956 and the coverage of the population serviced by water fluoridation gradually increased. By 2007 the only highly populated areas which did not have access to a fluoridated public water supply were the Shires of Ballina and Byron and the Local Government Area (LGA) of Gosford. It is NSW Health's policy to encourage LGAs to implement water fluoridation [2].

In 2007, Gosford City Council voted to fluoridate the water supply and the scheme was gazetted to be implemented in December 2008. The NSW Health Centre for Oral Health Strategy decided to monitor the dental health of 10-13 year old children just after the scheme began in 2009 with a follow up assessment two years later in 2011. The rationale for this decision was threefold:

i. To gain baseline data on the oral health of 10-13 year old children in Gosford soon after water fluoridation began.

ii. To compare over time the oral health of 10-13 year old children in the Gosford LGA with children living in a LGA which had been fluoridated for over 40 years and with children living in Shires which had no immediate plans to fluoridate.

iii. A systematic review of water fluoridation, often called the York Report [3], had commented that there was a need to monitor the success of fluoridation in the post-fluoride toothpaste era in order to determine if it still offered a positive benefit in terms of a caries reduction when compared with communities without access to this public health measure.

This paper reports on the baseline oral health of the 10-13 year old children in 2009 in the three study areas and investigates whether any changes had occurred in 2011.

Methods

Gosford City LGA on the Central Coast of NSW implemented a new water fluoridation scheme in December 2008. A comparator LGA, Wyong, also on the Central Coast which has been fluoridated for over 40 years was the active control, whilst the Shires of Ballina and Byron in Northern NSW were the non-fluoridated control areas. The concentration of fluoride in the public water supplies in NSW is carefully monitored and maintained at approximately 1 ppm. The non-fluoride comparison sites were more difficult to identify given the widespread coverage of fluoridation in NSW [4].

A sample size calculation suggested 450 children were required per location. The participants were drawn from Catholic and State Schools in the three areas, which were randomly selected from a master list until the individual school rolls for 10-13 year old children added up to around 900. The over sampling was to allow for a high non response rate as a previous study [5] had reported that fluoridation was a very emotive issue in the Shires of Ballina and Byron and many parents were reluctant to allow their children to have a dental inspection, so over sampling was a necessity.

The first study was undertaken in September to November 2009 and the follow up took place in the same months of 2011. The children were examined in the school utilising portable dental equipment, including an illuminated mirror with a disposable head, a mini compressor and a light weight dental chair. The examiners, two dentists and four dental therapists, were trained and calibrated to use the same diagnostic system as that adopted in the 2007 NSW Statewide Child Dental Health Survey [6] which consisted of a visual examination of an air dried tooth under a bright light. Caries was diagnosed if there was a visible break in the enamel and/or a clearly delineated dark shadow under the enamel. A probe was not used to assist diagnosis and bitewing radiographs were not taken [7].

As part of the consent process, the parent carers were asked to record their educational attainment, their child's toothbrushing frequency and sugary drink consumption (including sugar sweetened fruit juices, cordial, cola and other fizzy drinks). Indigenous status was also collected.

Before each examination year, extensive examiner training took place at a central location to ensure consistency with the diagnostic criteria [8]. The same team of examiners was used in 2009 and 2011. A gold standard examiner undertook five joint dental inspections with each of the six study examiners who also re-examined 10% of the participants. Data were entered directly into a customized Microsoft Access database on laptop computers and then analysed using SAS version 9.3.

Caries experience was measured using the dmft and DMFT indices, the percent caries free, and the Significant Caries Index (SiC) according to each geographical location. The SiC Index records the highest 30 percent of dmft/DMFT scores and the SiC^{10} records the highest ten percent of dmft/DMFT scores. The SiC identifies those individuals with the greatest burden of disease in the three study areas [9,10].

A high proportion of children in all sites (Table 2) had zero scores for dmft and DMFT, so a negative binomial model was best suited to conduct multivariate analysis of these data. However the presence of caries is a binary variable for which logistic regression is best suited for assessing test factors associated with caries activity. Backward stepwise regression was used to select the best models and the most influential covariates. The following covariates were tested:

- Fluoridation status
- Number of permanent teeth present
- Whether or not a dental visit had occurred following toothache in the last 3 months
- Sweet drink consumption

- Concession card holder status
- Gender

Sweet drink consumption (impact of flavoured milk was the strongest sweet drink factor in both the 2009 and 2011 dmft models. However fizzy drinks or the total sweet drinks in general were more influential than flavoured milk in the adult teeth models).

The study was approved by the State Education Research Committee (SERAP) of the NSW Department of Education and Training. The Catholic Education Commission also gave permission to involve schools within their jurisdiction (SERAP number 2008052). The Sydney West Area Health Service (SWAHS) Human Research Ethics Committee granted ethical approval for the school based surveys; HEREC 2008/314 18 (2758); All RED08/WMEAD/57. The research was conducted in full accordance with the World Medical Association Declaration of Helsinki.

Results

Three thousand seven hundred and ten (3710) children aged 10-13 years in Gosford and Wyong LGAs and the Shires of Ballina/Byron received a dental examination at school in the years 2009 and 2011. Table 1 shows that the response rate varied slightly over time. The non-fluoridated Shires of Ballina and Byron returned the lowest number of positive consents; 48.2 percent in 2009 and 50.4 percent in 2011. The two fluoridated areas (Table 1) consistently had positive consent rates over 65% in 2009 and 2011. The mean age of the participants was similar for all areas overtime and the gender balance was not markedly different (Table 1).

Table 1: Consent rates for the three study areas, mean age of the participants and gender balance for years 2009 and 2011.

Fluoridation Status	N of consents issued	N of children examined	% response rate	Mean age in years	% Males
Year 2009					
Fluoridated	1142	783	68.6	11.8	49.3
Newly fluoridated	1109	777	70.0	11.5	48.4
Not fluoridated	904	436	48.2	11.9	51.9
Year 2011					
Fluoridated	927	617	66.5	11.8	49.0
Newly fluoridated	913	642	70.3	11.6	47.8
Not fluoridated	903	455	50.4	11.8	52.3

Nearly seven percent (6.6%; n=246) of the total sample (3710) for the three areas in 2009 and 2011 were reported to be Aboriginal. The numbers were too small to be included in the analysis as they were spread over the three areas.

A gold standard examiner completed five joint examinations with each of the six individual study examiners, in 2009 and 2011. There were high levels of agreement in both the dmft and DMFT scores. In 2009 Intra Class Correlations ranged from +74 to 0.93 for the dmft index and +0.71 to 0.89 for the DMFT index. In 2011 the ICCs were +0.68 to 0.91 for dmft and +0.74 to 0.91 for DMFT [11].

Table 2 shows that in 2009 the mean dmft and DMFT scores for the three areas were different. The fluoridated area had a mean dmft score of 0.40 and a DMFT of 0.48. The non-fluoridated area had a mean dmft score of 0.74 and DMFT of 0.99, whilst the newly fluoridated area had a dmft score of 0.68 and a DMFT of 0.59. Similar differences in oral health between the three areas were highlighted by the SiC and the modified SiC (Table 2; DMFT + dmft). In 2009, the non-fluoridated (SiC 2.47; $SiC^{modified}$ 4.89) and the newly fluoridated (SiC 2.26;SiC modified 4.04) areas had scores that were almost double that of the fluoridated area (SiC 1.32; $SiC^{modified}$ 2.94).

The data presented in Table 2 for the year 2011 shows that the mean dmft and DMFT scores had fallen in all three areas. The fluoridated area had a mean dmft of 0.32 and a DMFT of 0.38; The non-fluoridated area had a dmft of 0.67 and a DMFT of 0.71 and the newly fluoridated area had a dmft of 0.44 and a DMFT of 0.45. The reductions in caries between 2009 and 2011 were most marked in those participants with a significant caries problem who lived in the newly fluoridated area, their mean SiC score dropped from 2.26 to 1.48; a reduction of 34.5%. In the non-fluoridated area, reductions in dmft/ DMFT were modest and there was only a marginal change in the SiC, from 2.47 to 2.22, which was a 10 % reduction.

For children with the highest 10% of dmft and DMFT scores ($SiC^{modified}$) Table 2 highlights the benefits of fluoridation. In 2011 The modified SiC mean score in the fluoridated area was 2.39, and 3.11 for the newly fluoridated area, which was not matched to the same extent in the non-fluoridated location ($SiC^{modified}$ 4.20). Both the SiC indices show that there is are large differences in the burden of dental disease in these three locations in NSW.

The proportions of children caries free in 2009 according to area were fluoridated (60%), non-fluoridated (49%) and newly fluoridated (49%). These proportions had changed in 2011. In the fluoridated area 66% were caries free compared with 51% in the non-fluoridated location. However, the proportion of children caries free in the newly fluoridated area improved by 10% to 60% (Table 2).

Table 2: The dental health of 11-13 year olds in fluoridated and non- fluoridated areas of NSW in 2009 and 2011.

		Fluoridated		No Fluoridation		Newly fluoridated		All sites	
		2009	2011	2009	2011	2009	2011	2009	2011
No of children	N	783	617	436	455	777	642	1996	1714
dmft	Mean	0.40	0.32	0.74	0.67	0.68	0.44	0.58	0.46
DMFT	Mean	0.48	0.38	0.99	0.71	0.59	0.45	0.63	0.49
dmft/DMFT	Mean	0.87	0.70	1.73	1.38	1.27	0.90	1.22	0.95
%dmft=0	%	80.0	81.7	73.9	72.8	70.0	77.4	74.8	77.7
%DMFT=0	%	73.6	79.3	62.4	67.5	67.6	75.7	68.8	74.8
%dmft/DMFT=0	%	60.4	66.1	48.9	51.4	49.4	60.4	53.6	76.1
dt	Mean	0.20	0.17	0.45	0.36	0.31	0.25	0.30	0.25
DT	Mean	0.22	0.17	0.46	0.41	0.31	0.21	0.31	0.25
DT+dt	Mean	0.42	0.34	0.92	0.77	0.62	0.46	0.61	0.50
mt	Mean	0.04	0.01	0.01	0.03	0.01	0.00	0.02	0.01
MT	Mean	0.07	0.05	0.07	0.03	0.02	0.04	0.05	0.04
MT+mt	Mean	0.10	0.06	0.08	0.06	0.03	0.05	0.07	0.06
ft	Mean	0.16	0.15	0.28	0.28	0.36	0.19	0.26	0.20
FT	Mean	0.19	0.16	0.46	0.27	0.26	0.20	0.28	0.20
FT+ft	Mean	0.35	0.30	0.74	0.55	0.62	0.39	0.54	0.40
SiC^{30}	Mean	1.32	1.07	2.47	2.22	2.26	1.48	1.94	1.53
$SiC^{Modified}$	Mean	2.94	2.39	4.89	4.20	4.04	3.11	3.85	3.25

For multivariate models, fluoridation status was the most influential covariate, and a statistically significant difference existed in all models when testing fluoridated vs non-fluoridated areas (Table 3).

Table 3: Multivariate Analysis of caries experience {percentage with decayed, missing or filled primary teeth (dmft)>0} according to year, fluoridation status, socio-economic characteristics and dental survey data.

	2009		2011	
	IRR	95% CI	IRR	95% CI
Fluoridation Status				
Fluoridated vs Non--fluoridated	1.91***	1.36-2.69	2.50 ***	1.74-3.60
Fluoridated vs Newly fluoridated	1.91***	1.45-2.53	1.24 NS	0.89-1.74
Non-fluoridated vs Newly fluoridated	1.00 NS	0.73-1.38	0.50 ***	0.35-0.70
Cardholder Status				
Non-Cardholder	-	-	1.37 *	1.03-1.81
Visit due to toothache (past 3 months)	-	-	0.40 ***	0.25-0.64
Count of permanent teeth present	1.28 ***	1.24-1.31	1.26***	1.22-1.29
Brushing Frequency				
2+ vs 1 brushes	0.87 NS	0.67-1.13	1.59 ***	1.17-2.17
2+ vs None	2.86 ***	1.52-5.39	0.88 NS	0.42-1.83
Once vs no brushes	2.49 **	1.31-4.76	1.81 NS	0.85-3.85

In 2009, the presence of caries (DMFT and dmft) showed a statistically significant difference, ($p<0.0001$ for primary teeth, $p<0.01$ for permanent teeth) between the fluoridated and newly fluoridated areas. The newly fluoridated and non-fluoridated areas were comparable in 2009. In contrast, for all models in 2011 the fluoridated vs newly fluoridated areas had comparable levels of caries, but the newly fluoridated vs non-fluoridated areas had statistically significant difference in caries prevalence ($p<0.001$).

The data presented in Table 3 shows that:

- In 2009, all children brushing their teeth at least once per day were less likely to have caries in their primary teeth than children not brushing teeth at all ($p<0.01$).
- In 2011, there was a statistically significant difference between children brushing once and 2+ times per day ($p<0.01$).
- In both cohorts, when a dental visit was preceded by toothache in the previous three months, the child was more likely to have caries in both adult and or primary teeth ($p<0.001$ in 2011, and $p<0.05$ for primary teeth in 2009).

Table 4 shows that for all three locations, there are a higher proportion of children with caries-free primary teeth in 2011 than 2009 (by 5-8%). In fluoridated and newly fluoridated areas there is a higher proportion of children with caries-free permanent teeth (5-9% increase in the cohort two years later) but a similar proportion for the un-fluoridated areas (75% in 2009, 73% in 2011).

Table 4: Proportion of children caries free across year and fluoridation status in the three locations.

		Fluoridated		Non- fluoridated		Newly fluoridated	
		2009	2011	2009	2011	2009	2011
Number of children	N	716	556	417	436	733	603
Caries free in primary teeth	%	74%	79%	62%	68%	68%	76%
Caries free in their adult teeth	%	79%	84%	75%	73%	69%	78%
Caries free in both sets of teeth	%	61%	68%	49%	52%	50%	61%

The impact of fluoridation is potentially most evident when the presence of caries is examined; a 7% improvement in the 2011 fluoridated cohort when compared to 2009; little change in the non-fluoridated cohort (49% in 2009 and 52% in 2011) and a larger improvement in the newly fluoridated location (50% in the 2009, to 61% in 2011).

Furthermore, the population without access to water fluoridation had the smallest proportion of caries-free children in 2011.

The cohort living in the established fluoride area reported that only 56-60% of children were brushing their teeth at least twice per day in 2009, and 2011, which is lower than the non-fluoridated and newly fluoridated locations (Table 5)

Table 5: Proportion of frequent brushers and those visiting the dentist due to toothache across year and fluoridation status in the three study locations.

		Fluoridated		Non- fluoridated		Newly Fluoridated	
		2009	2011	2009	2011	2009	2011
Number of children	N	716	556	417	436	733	603
Proportion brushing teeth at least twice per day	%	56%	60%	76%	78%	69%	69%
Proportion whose visit was due to toothache	%	9.5%	6.5%	9.1%	5.7%	7.2%	8.5%

Discussion

Fluoridation is a classic population based strategy to control dental caries. It does not rely on individuals consenting to actively join in a preventive or health promotion program. Indeed the majority of studies show that water fluoridation is an equitable and cost effective measure to reduce dental caries in both children and adults [12-14]. The Ministry of Health in NSW has adopted the fluoridation of public water supplies as one of its key oral health policies because the dental caries problem is widespread, has a greater prevalence in disadvantaged groups and its effectiveness is still evident despite the widespread use of fluoride toothpastes [15].

Water fluoridation still offers oral health benefits and does not rely on changing individual patterns of behavior. Whilst health promotion is certainly of value in highlighting how to reduce caries it does not offer an effective way to control or prevent caries on a population basis.

However it is clear that documenting the impact of water fluoridation is difficult and time consuming to organize and is complicated by multiple social risk factors.For example in our research project it was disappointing to note that many families in the Shires of Ballina and Byron did not consent for their children to join the study, but this is understandable as the local councils have been vehemently opposed to fluoridation and the bad publicity from an official body may have persuaded them not to return the consent forms. Therefore non response bias will be a factor that could well influence the validity of the results. Also it is conceivable that in our study the families who did not return consents would be more likely to come from

deprived areas with potentially higher levels of dental caries. Thus the reported caries rates for all three locations may be an underestimate. The return of consents is however a common problem for all public health researchers.

The strength of this research project is that it was designed as a prospective study with concurrent control groups. Oral health was evaluated at two time points which provides more useful information than cross-sectional studies, which would not have revealed the changes in caries prevalence that occurred in all the study sites. Clearly the time scale between examinations is short and it would be of value to repeat the study now that fluoridation is well established in Gosford LGA. The reductions in caries in the two fluoridated areas relate to how fluoride works. It impedes the demineralisation of dental enamel and enhances its remineralisation [16]. This topical mechanism of action explains how fluoridation can act relatively quickly once introduced into the public water supplies, as it offers a constant exposure to fluoride ions in the mouth [17-19]. The ability of fluoride to influence the demineralisation process of tooth enamel also means it will offer a benefit not only to children but adults as well[20]. Water fluoridation remains an efficient vehicle for delivering low concentrations of fluoride to large populations on a regular basis.

Conclusion

The results from this study show that water fluoridation continues to offer major oral health benefits to children. Never the less it is incumbent on the NSW State Government to fund regular surveillance studies to monitor the efficacy of water fluoridation over time.

Authors Contribution

Anthony Blinkhorn prepared the manuscript. Mrs Meredith Kay, formerly the manager of Northern Sydney and Central Coast Local Health District played a pivotal role in organising staff and transport facilities.

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Declaration

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