Government of **Western Australia**
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Dental Health Outcomes of Children Residing in Fluoridated and Non-Fluoridated Areas of Western Australia

Health Survey Unit

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Department of **Health**

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Executive Summary

This report presents the findings of a cross sectional study of 10,825 children aged 5 to12 years in 2011 and 2012 who presented at Dental Treatment Centres located in non-fluoridated areas of the South West of Western Australia and the Perth metropolitan area where the drinking water has been fluoridated for over 40 years.

The aim of the study was to determine if there was a difference in the prevalence of dental health outcomes in children that was associated with access to fluoridated water in Western Australia.

The findings suggested that children from non-fluoridated areas had poorer dental health outcomes than children from fluoridated areas including:

- A lower proportion of children aged 5 to 9 years with no dental caries in their deciduous teeth, with the difference being statistically significant for children aged 5 and 7 years.
- A significantly lower proportion of children aged 9 to 12 years with no caries in their permanent teeth.
- A significantly higher average number of missing permanent teeth for children aged 7 and 9 years.

After controlling for the effects of age, sex, Aboriginal status and having a record of an initial examination at a DTC, the findings indicated that children from non-fluoridated areas of South West WA still had poorer dental health outcomes than children from the fluoridated Perth metropolitan area and had:

- 1.5 times the odds of having one or more decayed, missing or filled deciduous teeth.
- 1.6 times the odds of having one or more decayed, missing or filled permanent teeth.

Introduction

Water fluoridation has been introduced in a number of countries across Europe, South America, North America and Asia (Cheng et al, 2007) yet remains a contentious issue for some individuals.

In the 1940s, evidence began to emerge through ecological cross-sectional studies and non-randomised controlled interventions that exposure to fluoride in the water supply was related to a dose-response reduction in dental caries [(Dean,1938), (Dean et al,1942)]. A Cochrane Library systematic review of 20 prospective studies with a concurrent control and which were measured over time found that water fluoridation is effective at reducing levels of tooth decay in children (Iheozor-Ejiofor et al, 2015).

The National Health and Medical Research Council (NHMRC) develops health advice for the Australian community, health professionals and government. In 2007 the NHMRC endorsed fluoridation of drinking water as a safe and effective measure to prevent dental decay (National Health and Medical Research Council, 2007). This position was reaffirmed in 2013.

The NHMRC recommend that water be fluoridated in the range of 0.6 to 1.1 mg/L, depending on climate, to balance reduction of dental caries and occurrence of dental fluorosis (National Health and Medical Research Council, 2007). The optimal fluoride concentration level is dependent on the environmental temperature (Galagan & Vermillion, 1957). As some public water supplies have naturally-occurring fluoride concentrations lower than that required to improve dental health outcomes, a controlled amount of fluoride is added to the public water supply to improve oral health in the population [(Cheng et al, 2007), (Spencer, 2006)].

A number of Australian studies have explored the association between caries and water fluoridation in children. Common oral health outcomes used to measure the effect of fluoridation on caries are the percentage of caries-free children in the population, and the numbers of decayed, missing and filled deciduous and permanent teeth, commonly referred to in oral epidemiology as the dmft/DMFT index, deciduous/permanent teeth respectively (National Health and Medical Research Council, 2012). The Significant Caries Index (SiC) and Significant Caries Index 10% (SiC^{10}) are measures used to compare dental outcomes between populations and describe the average caries experiences in the top one-third and one-tenth (respectively) of individuals within a population group (Nishi M et al, 2001).

Armfield (2005) found that average dmft results for children aged 5 to 6 years were significantly higher in non-fluoridated areas compared with fluoridated areas for 6 of 8 New South Wales (NSW) Area Health Services. Average DMFT results for children aged 11 to 12 years were also significantly higher in non-fluoridated areas for 6 of 10 NSW Area Health Services. For both dmft and DMFT analyses, average results were almost two fold higher in non-fluoridated compared with fluoridated areas.

Evans et al (2009) evaluated dmft for children aged 5 to 8 years at baseline and 10 years post introduction of fluoridation in the Blue Mountains and the neighbouring Hawkesbury area of NSW (already fluoridated at baseline). In 1993, the average dmft results for children from the Blue Mountains area was 41% higher compared with results for children from the Hawkesbury area. At the 10 year follow-up in 2003, children from the Blue Mountains area were 71% less likely to experience caries and average dmft was not significantly different when compared with children from the Hawkesbury area.

Spencer et al (2008) investigated the association between exposure to water fluoridation and incremental increases of dental caries in Queensland (Qld) and South Australia (SA). Higher lifetime exposure to fluoridated water was a significant predictor of lower caries increments for deciduous dentition for children from SA and Qld, while for permanent dentition water fluoridation was significant predictor for children from Qld after controlling for age, gender, other fluorides and socio-economic indicators.

Do and Spencer (2015) accounted for individual-level, school-level and area-level factors in a multi-level study of Queensland children and observed a significantly lower caries experience (up to 40% lower) for children from long-term fluoridated areas compared with children in non-fluoridated areas.

In Western Australia (WA), 92% of the State's population have access to fluoridated water, including the Perth metropolitan area which has been fluoridated for over 40 years [(National Health and Medical Research Council, 2012), (WA Department of Health, 2012)].

However, there are still pockets of non-fluoridated areas across Western Australia including in the South West of WA.

The aim of this study was to determine if there was a difference in the prevalence of dental health outcomes in children that was associated with access to fluoridated water in Western Australia.

Methodology

Western Australia has a total population of just over 2.2 million people, with almost three-quarters (74.3%) residing in the Perth metropolitan area which has been fluoridated for over 40 years. A further 6.9% of the population reside in the South West of WA, which contains pockets of non-fluoridated areas including the population centres of Bunbury, Busselton and Margaret River.

The study included all children aged 5 to 12 years who had a birth date on the 28th, 29th, 30th or 31st of the month who had presented at select Dental Treatment Centres (DTC) located in the non-fluoridated areas of the South West of WA and the fluoridated Perth metropolitan region during the period from January 2011 to December 2012. The non-fluoridated South West of WA population was defined in this study as children who attended the Adam Road, Australind, Bridgetown Mobile, Glen Huon, Margaret River Mobile, South Bunbury and West Busselton DTCs. In total, 10,825 children were included in the analysis. Of these 9,972 attended a Perth metropolitan DTC and 853 attended a DTC in the South West of WA.

Selecting children based on their birth date ensured minimal selection bias. Combining data from 2011 and 2012 increased the sample size, thus improving the reliability of the estimates.

Evaluation data collected by the Dental Health Services as part of service provision provided information of the first clinical examination in a calendar year.

The original text files were imported into Excel for initial data management and then analysed using SPSS Version 22.0. A number of data issues were identified following the initial interrogation of the raw data. A summary of issues and the corresponding management principles applied are outlined in Table 1.

Table 1: Data issues and management strategies

Raw data issue	Management
Date of birth missing	Cases with a missing date of birth were excluded
Sex missing	A case with unknown sex was excluded
Date of attendance outside the period 2011-2012	Episodes outside 2011 and 2012 were excluded
Invalid and unmatched Dental Treatment Centre (DTC) codes	Episodes with invalid and unmatched DTCs were excluded
Aboriginal status was not recorded or unknown	Aboriginal status was recoded to identify and include missing and unknown cases in the analysis
Multiple attendances	Primary and duplicate episodes of attendance were identified on the basis of date of birth, sex, Aboriginal status, DTC and attendance date. A review of the literature revealed one other study (Armfield, 2005) where the raw data included multiple episodes of care. The first episode of attendance only was included by Armfield, subsequently this current study has utilised a similar methodology including the first attendance only for cases with multiple episodes during 2011 and/or 2012

Descriptive statistics of the sample demographics and key dental outcomes by area of residence and age were examined. Key indicators for dental health, in this report, include the numbers of decayed, missing and filled deciduous and permanent teeth, for children aged 5 to 9 years and 6 to 12 years respectively. Clinicians at the Dental Treatment Centres use established diagnostic criteria to measure and report dental outcomes based on the World Health Organization (1997). Deciduous decay experience is recorded as the number of decayed (d), missing (m) and filled (f) teeth (dmft) with a maximum score of 20. Permanent decay experience is recorded as the number of decayed (D), missing (M) and filled (F) teeth (DMFT) with a maximum score of 28 or 32 if wisdom teeth are included.

Results are presented for individual years of age at examination for children aged five to nine. The sample size for children aged 10, 11 and 12 years of age in the South West of WA was too small to permit analysis by individual year of age. Therefore, to improve the reliability of estimates, data is presented for children 10 to 11 years and 11 to 12 years. A decision was made not to group all three ages together due to potential differences in the caries experience of a 10 year old compared to a 12 year old. The caries experience immediately after tooth eruption is likely to be similar with any deviation due to other factors more likely to present later.

The Significant Caries Index (SiC) and Significant Caries Index 10% (SiC^{10}) were used to describe the average caries experiences in the top one-third and one-tenth (respectively) of individuals within a population group (Nishi M et al, 2001). Due to the relatively low proportion of children with caries in the study population, the SiC^{10} was used to compare caries experiences for children by age group, area, and with national findings obtained from the 2007 National Child Dental Health Survey (Meija GC et al, 2012).

To determine whether there was an association between area of residence (and thus exposure to fluoride in drinking water) and having one or more decayed, missing or filled deciduous teeth among children aged 5 to 12 years, univariate logistic regression models (results not shown) were fitted, with the findings informing the construction of a series of multivariate logistic regression models that controlled for other available explanatory variables.

Results

Demographics

The total sample size was 10,825 children aged between 5 and 12 years. Table 2 shows that the age distribution of children was similar in both areas, with the highest proportion of children aged 5 years.

Table 2: Age distribution of children by area, 2011-2012

Age in years	Metropolitan (fluoridated)		South West (non-fluoridated)	
	N	%	N	%
5 years	1,700	17.0	163	19.1
6 years	1,293	13.0	109	12.8
7 years	1,292	13.0	110	12.9
8 years	1,214	12.2	102	12.0
9 years	1,133	11.4	104	12.2
10 years	1,134	11.4	92	10.8
11 years	1,196	12.0	80	9.4
12 years	1,010	10.1	93	10.9
All ages	9,972	100.0	853	100.0

The distribution of children who identified as Aboriginal by age was similar for the metropolitan and South West of WA (Table 3) and there was no difference in the overall proportion (excluding unknown) who identified as Aboriginal (2.5% cf. 3.0%, χ^2, p=0.256). However, the overall proportion of children with unknown Aboriginal status was higher in the South West of WA compared with the metropolitan area (5.0% cf. 1.6%, χ^2, p=<0.001).

Table 3: Aboriginal status of children by area and age in years, 2011-2012

Age in years	Metropolitan (fluoridated)				South West (non-fluoridated)			
	ATSI		Unknown		ATSI		Unknown	
	N	%	N	%	N	%	N	%
5 years	42	2.5	23	1.4	5	3.1	6	3.7
6 years	35	2.7	34	2.6	3	2.8	7	6.4
7 years	47	3.6	17	1.3	6	5.5	4	3.6
8 years	25	2.1	16	1.3	1	1.0	4	3.9
9 years	23	2.0	24	2.1	1	1.0	7	6.7
10 years	28	2.5	17	1.5	5	5.4	6	6.5
11 years	25	2.1	15	1.3	1	1.3	6	7.5
12 years	25	2.5	17	1.7	4	4.3	3	3.2
All ages	250	2.5	163	1.6	26	3.0	43	5.0

There was some variability in the age distribution of children who were having their first examination at a DTC, with younger children more likely to have had an initial DTC examination (Table 4). Overall, the proportion of children who had an initial DTC examination was lower for children from the South West of WA compared with the metropolitan area (24.5% cf. 29.2%, χ^2, p=0.004).

Table 4: Number and proportion of children who had an initial DTC examination by area and age in years, 2011-2012

Age in years	Metropolitan (fluoridated)		South West (non-fluoridated)	
	N	%	N	%
5 years	1,571	92.4	143	87.7
6 years	611	47.3	33	30.3
7 years	200	15.5	12	10.9
8 years	132	10.9	4	3.9
9 years	107	9.4	2	1.9
10 years	112	9.9	4	4.3
11 years	100	8.4	8	10.0
12 years	79	7.8	3	3.2
All ages	2,912	29.2	209	24.5

Dental Outcomes

Decayed, missing and filled deciduous teeth

Table 5 shows the numbers of decayed, missing or filled deciduous teeth for children aged 5 to 9 years by age and area of residence.

The proportion of children having any caries increased with age at examination, as did the number of teeth affected. In respect to area of residence, the proportion of children without any dental caries was consistently higher for children from the metropolitan area compared with the South West of WA, however the differences were only statistically significant for children aged 5 and 7 years (5 years: 71.4% cf. 59.7%, χ^2, p=<0.001; 7 years: 56.4% cf. 44.5%, χ^2, p=0.02).

Table 5: Total numbers and proportions of decayed, missing or filled deciduous teeth for children aged 5 to 9 years by area, 2011-2012

N of decayed, missing or filled deciduous teeth	Children aged 5 years				Children aged 6 years				Children aged 7 years				Children aged 8 years				Children aged 9 years			
	Metropolitan		South West		Metropolitan		South West		Metropolitan		South West		Metropolitan		South West		Metropolitan		South West	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
0	1,213	71.4	89	59.7	837	64.7	61	56.0	729	56.4	49	44.5	630	51.9	45	44.1	561	49.5	45	43.3
1 to 2	243	14.3	36	24.2	200	15.5	20	18.3	253	19.6	25	22.7	258	21.3	24	23.5	289	25.5	23	22.1
3 to 5	139	8.2	16	10.7	120	9.3	17	15.6	180	13.9	21	19.1	234	19.3	20	19.6	210	18.5	27	26.0
6+	105	6.2	8	5.4	136	10.5	11	10.1	130	10.1	15	13.6	92	7.6	13	12.7	73	6.4	9	8.7
Total	1,700	100.0	149	100.0	1,293	100.0	109	100.0	1,292	100.0	110	100.0	1,214	100.0	102	100.0	1,133	100.0	104	100.0

Figure 1 illustrates the proportion of children aged 5 to 9 years who had evidence of one or more dental caries.

Figure 1: Proportion of children with one or more decayed, missing or filled deciduous teeth for children aged 5 to 9 years by area, 2011-2012

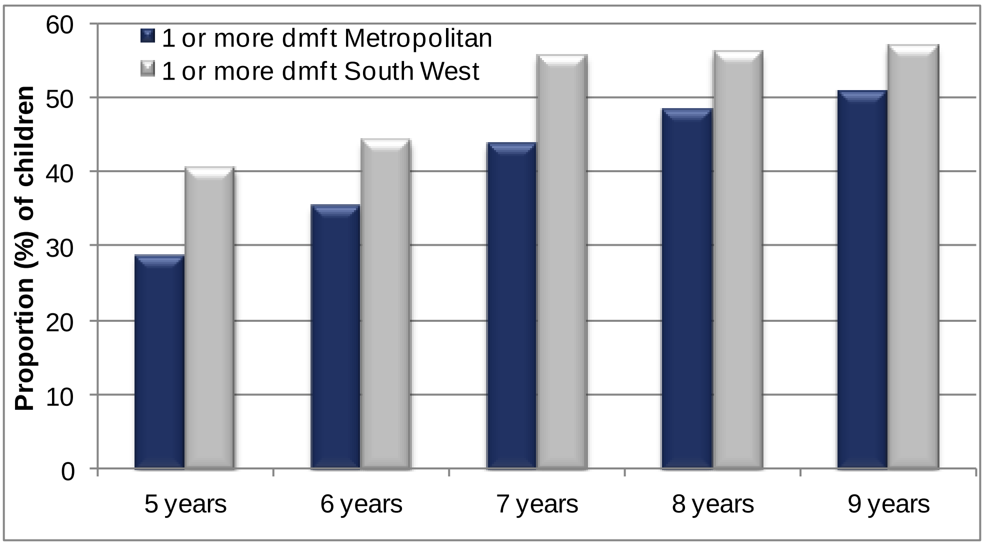


Table 6 shows the average number of decayed, missing and filled deciduous teeth, and average dmft scores by age and area, for children aged 5 to 9 years. Figure 2 illustrates the cumulative results for the average d, m and f scores. Average dmft scores were highest for children aged 7 or 8 years in both the metropolitan and South West areas.

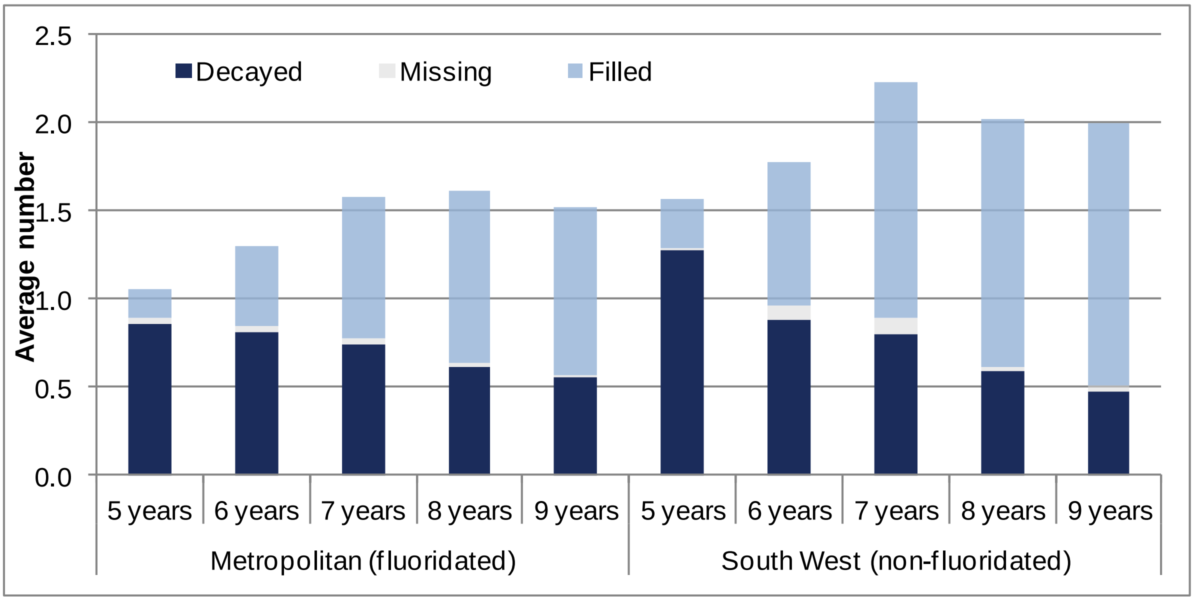
Significant findings for children attending the South West of WA DTCs compared with the metropolitan area included a higher average number of decayed deciduous teeth for children aged 5 years, a higher average number of filled deciduous teeth for children aged 7 and 9 years as well as a higher average dmft score for children aged 5 years.

Table 6: Average numbers of decayed, missing, filled deciduous teeth and total count, children 5 to 9 years by area, 2011-2012

Age in years	Metropolitan (fluoridated)		South West (non-fluoridated)		Significant difference from Metropolitan*
	Average	95% CI	Average	95% CI	
5 years					
Decayed teeth (d)	0.9	(0.77 - 0.94)	1.3	(1.01 - 1.54)	↑
Missing teeth (m)	0.0	(0.02 - 0.06)	0.0	(0.00 - 0.02)	ns
Filled teeth (f)	0.2	(0.12 - 0.19)	0.3	(0.14 - 0.43)	ns
dmft	1.1	(0.95 - 1.15)	1.6	(1.27 - 1.88)	↑
6 years					
Decayed teeth (d)	0.8	(0.71 - 0.91)	0.9	(0.53 - 1.24)	ns
Missing teeth (m)	0.0	(0.02 - 0.05)	0.1	(0.00 - 0.20)	ns
Filled teeth (f)	0.5	(0.38 - 0.52)	0.8	(0.51 - 1.11)	ns
dmft	1.3	(1.17 - 1.43)	1.8	(1.21 - 2.33)	ns
7 years					
Decayed teeth (d)	0.7	(0.65 - 0.83)	0.8	(0.46 - 1.14)	ns
Missing teeth (m)	0.0	(0.02 - 0.06)	0.1	(0.01 - 0.17)	ns
Filled teeth (f)	0.8	(0.71 - 0.89)	1.3	(0.93 - 1.74)	↑
dmft	1.6	(1.44 - 1.72)	2.2	(1.65 - 2.80)	ns
8 years					
Decayed teeth (d)	0.6	(0.54 - 0.69)	0.6	(0.35 - 0.83)	ns
Missing teeth (m)	0.0	(0.00 - 0.04)	0.0	(0.00 - 0.07)	ns
Filled teeth (f)	1.0	(0.88 - 1.07)	1.4	(0.99 - 1.81)	ns
dmft	1.6	(1.49 - 1.74)	2.0	(1.54 - 2.50)	ns
9 years					
Decayed teeth (d)	0.5	(0.48 - 0.62)	0.5	(0.28 - 0.66)	ns
Missing teeth (m)	0.0	(0.00 - 0.03)	0.0	(0.00 - 0.11)	ns
Filled teeth (f)	1.0	(0.86 - 1.05)	1.5	(1.09 - 1.90)	↑
dmft	1.5	(1.40 - 1.64)	2.0	(1.52 - 2.48)	ns

*Determined by comparing confidence intervals, where intervals that do not overlap are deemed significantly different (arrow denotes direction); ns = not significant.

Figure 2: Average numbers of decayed, missing, filled deciduous teeth and total count, children 5 to 9 years by area, 2011-2012



Decayed, missing and filled permanent teeth

Table 7 shows the numbers of decayed, missing or filled permanent teeth for children aged 6 to 12 years by age and area of residence.

The proportion of children having any caries and the total number of caries increased with age at examination. In agreement with the findings for deciduous teeth, the proportion of children with no caries in their permanent teeth was consistently higher for children from the metropolitan area compared with the South West of WA, and differences were significant for children aged 9 to 12 years (9 years: 85.1% cf. 77.9%, χ^2, p=0.05; 10 to 11 years: 77.1% cf. 67.4%, χ^2, p=<0.001; 11 to 12 years: 71.4% cf. 60.7%, χ^2, p=<0.001). The percentages of children with one or more caries by age group and area of residence are illustrated in Figure 3 and Figure 4.

Table 7: Total numbers and proportions of decayed, missing or filled permanent teeth for children aged 6 to 12 years by area, 2011-2012

N of decayed, missing or filled permanent teeth	Children aged 6 years				Children aged 7 years				Children aged 8 years			
	Metropolitan		South West		Metropolitan		South West		Metropolitan		South West	
	N	%	N	%	N	%	N	%	N	%	N	%
0	1,256	97.1	101	92.7	1,187	91.9	99	90.0	1,060	87.4	84	82.4
1 to 2	32	2.5	7	6.4	92	7.1	9	8.2	131	10.8	16	15.7
3 to 5	5	0.4	1	0.9	13	1.0	1	0.9	18	1.5	2	2.0
6+	0	0.0	0	0.0	0	0.0	1	0.9	4	0.3	0	0.0
Total	1,293	100.0	109	100.0	1,292	100.0	110	100.0	1,213	100.0	102	100.0
N of decayed, missing or filled permanent teeth	**Children aged 9 years**				**Children aged 10-11 years**				**Children aged 11-12 years**			
	Metropolitan		**South West**		**Metropolitan**		**South West**		**Metropolitan**		**South West**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
0	964	85.1	81	77.9	1,796	77.1	116	67.4	1,574	71.4	105	60.7
1 to 2	144	12.7	17	16.3	426	18.3	45	26.2	474	21.5	48	27.7
3 to 5	24	2.1	6	5.8	99	4.2	9	5.2	146	6.6	19	11.0
6+	1	0.1	0	0.0	9	0.4	2	1.2	12	0.5	1	0.6
Total	1,133	100.0	104	100.0	2,330	100.0	172	100.0	2,206	100.0	173	100.0

Figure 3: Proportions of children with one or more decayed, missing or filled permanent teeth for children aged 6 to 9 years by area, 2011-2012

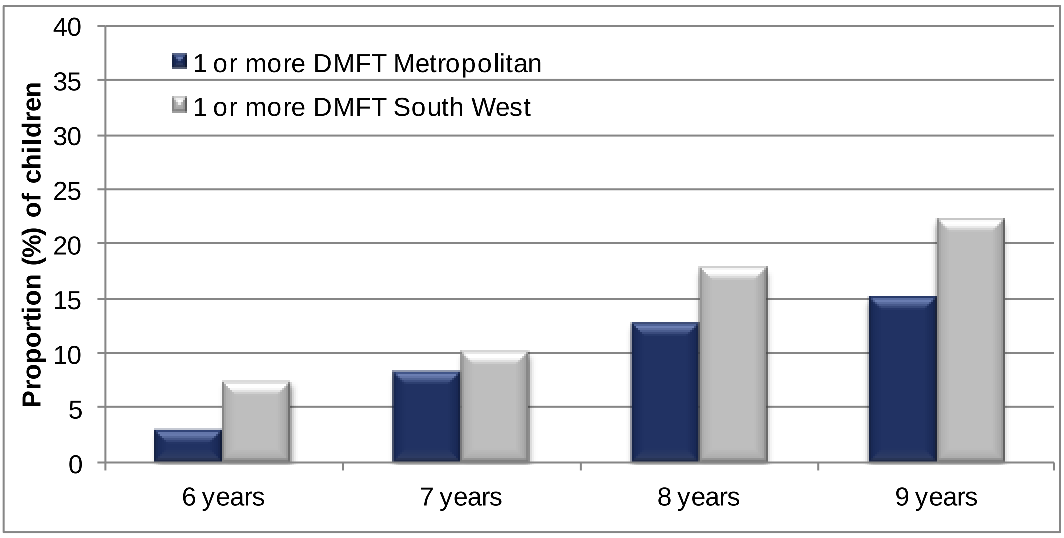


Figure 4: Proportions of children with one or more decayed, missing or filled permanent teeth for children aged 10 to 12 years by area, 2011-2012

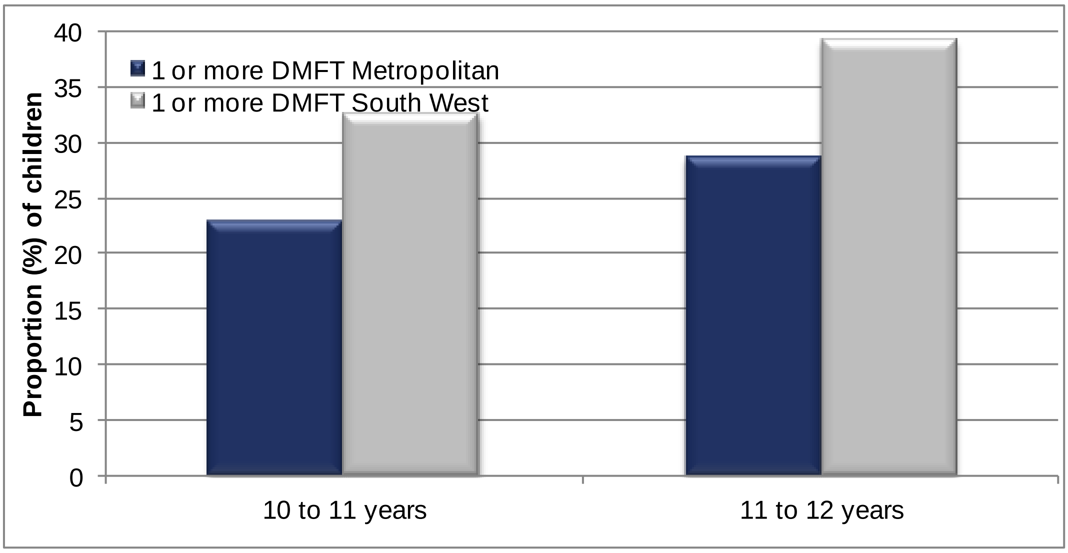


Table 8 shows the average number of decayed, missing and filled permanent teeth, and average DMFT scores by age and area for children aged 6 to 9 years. The average number of missing teeth was significantly higher for children aged 7 and 9 years from the South West of WA compared with the metropolitan area.

Table 8: Average numbers of decayed, missing, filled permanent teeth and total count, children 6 to 9 years by area, 2011-2012

Age in years	Metropolitan (fluoridated) Average	Metropolitan (fluoridated) 95% CI	South West (non-fluoridated) Average	South West (non-fluoridated) 95% CI	Significant difference from Metropolitan*
6 years					
Decayed teeth (D)	0.04	(0.03 - 0.06)	0.07	(0.02 - 0.13)	ns
Missing teeth (M)	0.00	(0.00 - 0.00)	0.00	(0.00 - 0.00)	ns
Filled teeth (F)	0.00	(0.00 - 0.01)	0.04	(0.00 - 0.11)	ns
DMFT	0.05	(0.03 - 0.07)	0.11	(0.02 - 0.20)	ns
7 years					
Decayed teeth (D)	0.10	(0.08 - 0.12)	0.07	(0.01 - 0.13)	ns
Missing teeth (M)	0.00	(0.00 - 0.00)	0.02	(0.00 - 0.05)	↑
Filled teeth (F)	0.03	(0.01 - 0.04)	0.11	(0.00 - 0.25)	ns
DMFT	0.13	(0.10 - 0.16)	0.20	(0.05 - 0.35)	ns
8 years					
Decayed teeth (D)	0.14	(0.10 - 0.17)	0.12	(0.05 - 0.19)	ns
Missing teeth (M)	0.01	(0.00 - 0.02)	0.00	(0.00 - 0.00)	ns
Filled teeth (F)	0.07	(0.05 - 0.09)	0.17	(0.06 - 0.28)	ns
DMFT	0.22	(0.18 - 0.26)	0.28	(0.14 - 0.43)	ns
9 years					
Decayed teeth (D)	0.14	(0.11 - 0.17)	0.20	(0.10 - 0.30)	ns
Missing teeth (M)	0.02	(0.01 - 0.03)	0.09	(0.07 - 0.12)	↑
Filled teeth (F)	0.09	(0.07 - 0.12)	0.20	(0.07 - 0.34)	ns
DMFT	0.25	(0.21 - 0.30)	0.40	(0.23 - 0.58)	ns

*Determined by comparing confidence intervals, where intervals that do not overlap are deemed significantly different (arrow denotes direction); ns = not significant.

For children aged 10 to 11 years, the average number of filled permanent teeth was higher for children from the South West of WA compared with the metropolitan area (Table 9).

Table 9: Average numbers of decayed, missing, filled permanent teeth and total count, children aged 10 to 12 years by area, 2011-2012

Age in years	Metropolitan (fluoridated) Average	Metropolitan (fluoridated) 95% CI	South West (non-fluoridated) Average	South West (non-fluoridated) 95% CI	Significant difference from Metropolitan*
10-11 years					
Decayed teeth (D)	0.21	(0.17 - 0.24)	0.30	(0.14 - 0.46)	ns
Missing teeth (M)	0.02	(0.01 - 0.03)	0.00	(0.00 - 0.00)	ns
Filled teeth (F)	0.22	(0.19 - 0.24)	0.37	(0.24 - 0.49)	↑
DMFT	0.44	(0.39 - 0.49)	0.67	(0.46 - 0.88)	ns
11-12 years					
Decayed teeth (D)	0.29	(0.23 - 0.34)	0.35	(0.24 - 0.46)	ns
Missing teeth (M)	0.03	(0.02 - 0.04)	0.05	(0.00 - 0.10)	ns
Filled teeth (F)	0.29	(0.26 - 0.32)	0.41	(0.28 - 0.54)	ns
DMFT	0.60	(0.54 - 0.66)	0.82	(0.62 - 1.01)	ns

Figure 5 and Figure 6 illustrate the cumulative results for average numbers of decayed, missing and filled teeth by area and age group. Average DMFT scores were highest for children aged 8 or 9 years in both the metropolitan and South West areas.

Figure 5: Average numbers of decayed, missing, filled permanent teeth and total count, children aged 6 to 9 years by area, 2011-2012

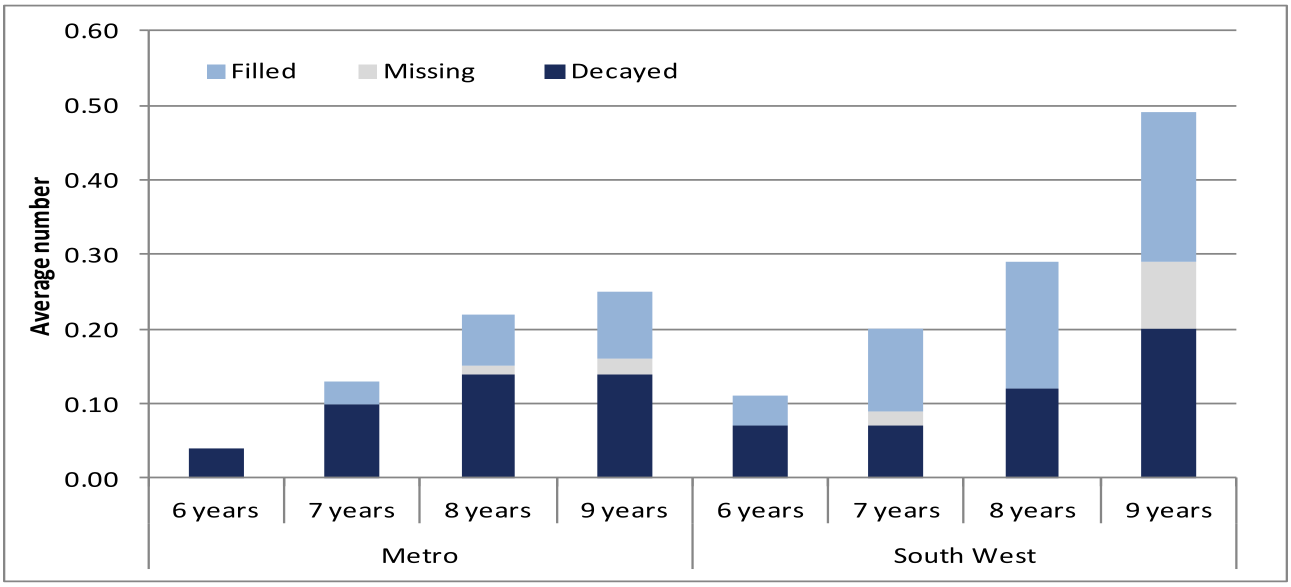
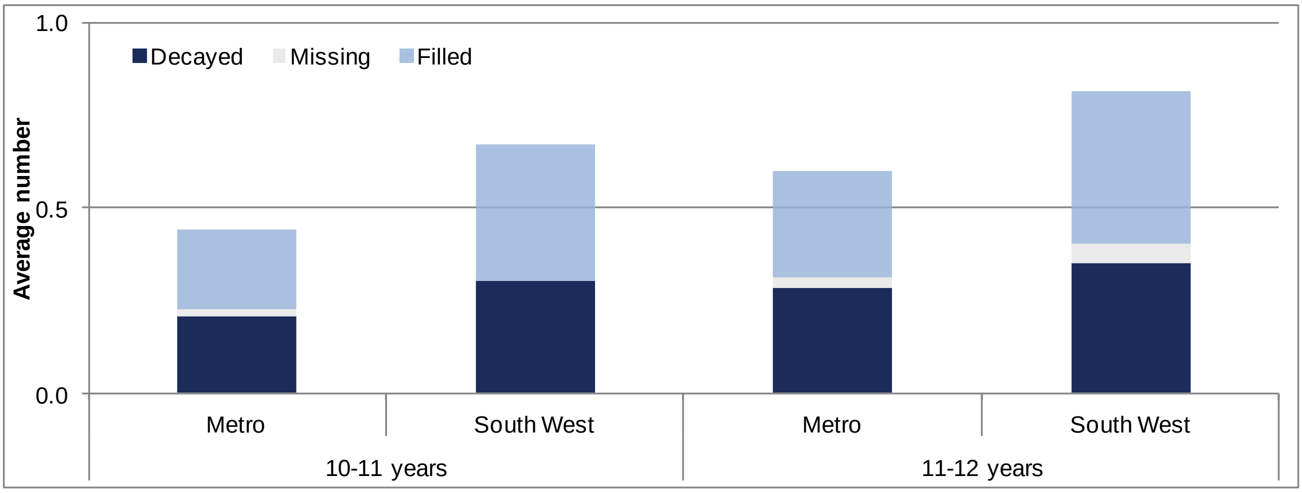


Figure 6: Average numbers of decayed, missing, filled permanent teeth and total count, children aged 10 to 12 years by area, 2011-2012



Significant caries index (10%), deciduous teeth

The significant caries index 10% (SiC[10]) provides information on the average dmft and DMFT scores for the one-tenth of children (top decile) with the highest numbers of caries.

Table 10 and Figure 7 show the comparative results for SiC[10] and average dmft scores for deciduous teeth in children, 5 to 9 years, by age and area.

SiC[10] scores for deciduous teeth were highest for younger children and declined with age at examination, as deciduous teeth made way for permanent teeth. For children from the metropolitan area, SiC[10] scores ranged from 2.9 to 7.5, while for children from the South West of WA, SiC[10] scores ranged from 2.8 to 9.4.

Overall, children aged 6 years from both areas had the highest SiC[10] scores. The difference between SiC[10] and average dmft scores was greatest for children aged 7 years from both areas (Metropolitan difference: 5.7; South West of WA difference: 9.4).

Table 10: SiC[10] and average dmft scores, deciduous teeth, children aged 5 to 9 years, by age and area, 2011-2012

Age group	SiC 10		Ave. dmft	Ave. dmft
	Metropolitan	South West	Metropolitan	South West
5 years	6.7	7.9	1.1	1.6
6 years	7.5	9.4	1.3	1.8
7 years	5.7	9.4	1.6	2.2
8 years	4.4	7.2	1.6	2.0
9 years	2.9	2.8	1.5	2.0

Figure 7: SiC[10] and average dmft scores, deciduous teeth, children aged 5 to 9 years, by age and area, 2011-2012

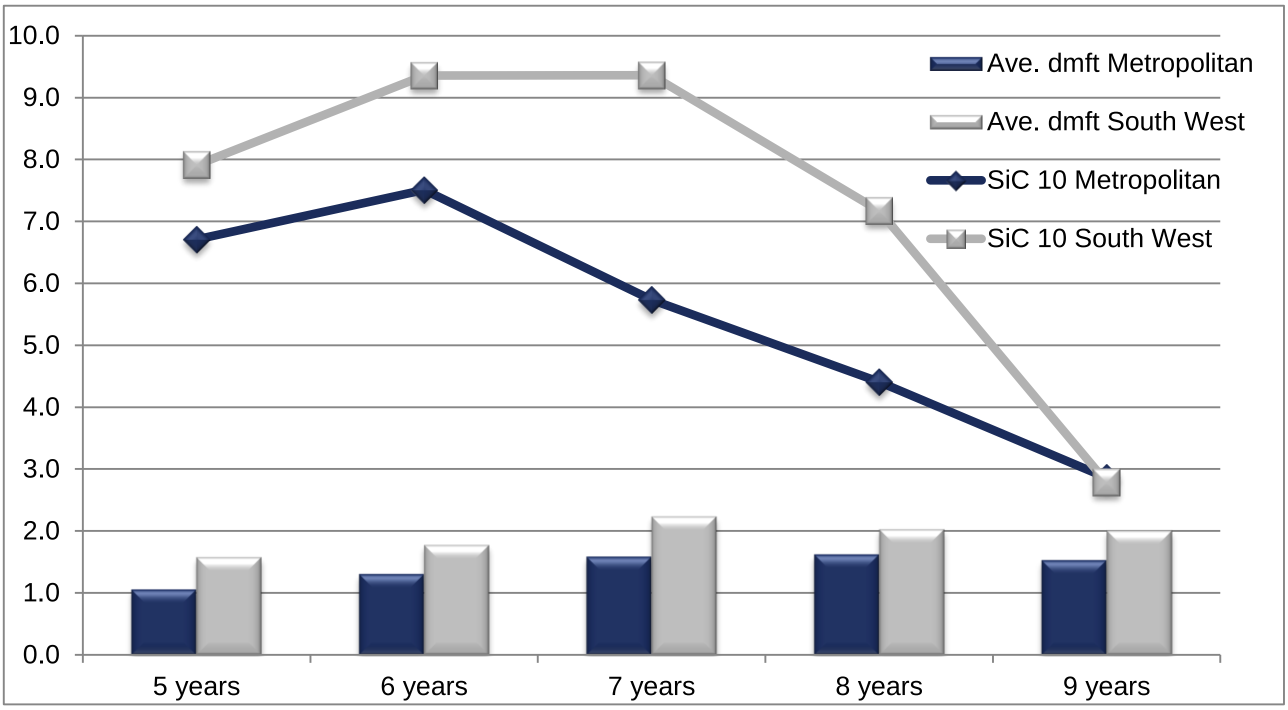
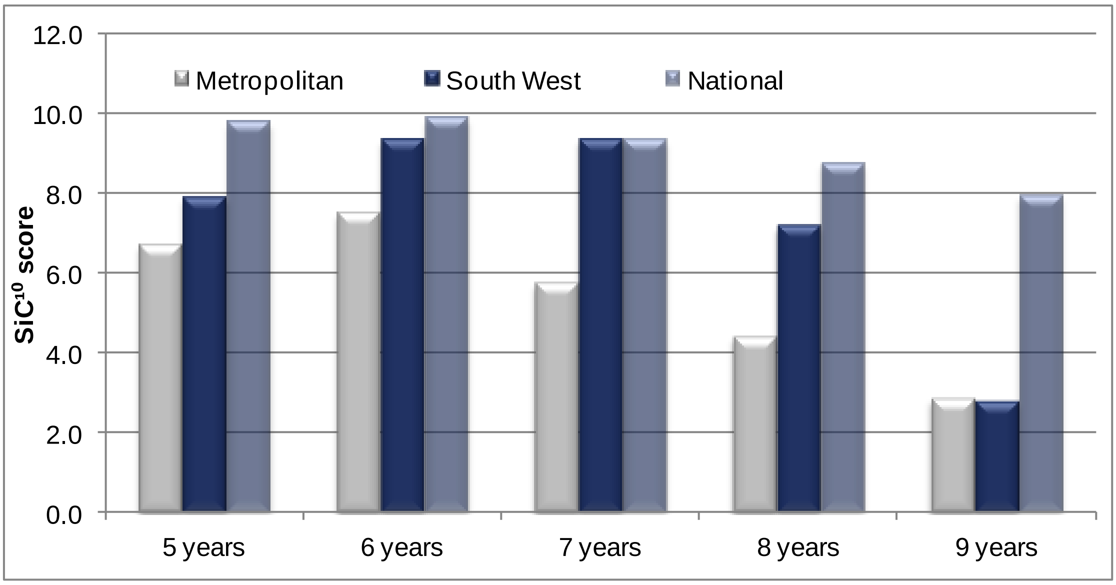


Figure 8 shows SiC^{10} scores for deciduous teeth (dmft) for children aged 5 to 9 years from the metropolitan and South West of WA (2011-2012), and the national SiC^{10} scores from the 2007 National Child Dental Health Survey. While SiC^{10} scores for children from the metropolitan area and South West of WA were generally lower than the national averages, the results for children aged 6 and 7 years from the South West of WA were comparable with the national averages.

Figure 8: SiC^{10} scores, deciduous teeth, children aged 5 to 9 years, metropolitan, South West (2011-2012) and national (2007)



Note: National data obtained from Mejia et al, 2012

Significant caries index (10%), permanent teeth

SiC^{10} index and average DMFT scores for permanent teeth in children 6 to 12 years are shown in Table 11 and Figure 9. In contrast to the deciduous SiC^{10} analysis, SiC^{10} index scores for permanent teeth were lowest for children aged 6 to 7 years, and increased with age at examination as children's number of permanent teeth increased.

For permanent teeth, children aged 10 to 11 years from both areas had the highest SiC^{10} scores. In the metropolitan area, SiC^{10} scores ranged from 0.5 to 3.0, while for children from the South West of WA, SiC^{10} scores ranged from 1.1 to 3.8.

Table 11: SiC[10] and average DMFT scores, permanent teeth, children aged 6 to 12 years, by age and area, 2011-2012

Age	SiC 10		Ave. DMFT	
	Metropolitan	South West	Metropolitan	South West
6 years	0.5	1.1	0.0	0.1
7 years	1.3	2.0	0.1	0.2
8 years	1.9	2.1	0.2	0.3
9 years	2.5	2.8	0.3	0.4
10-11 years	3.0	3.8	0.4	0.7
11-12 years	2.7	3.7	0.6	0.8

Figure 9: SiC[10] and average DMFT scores, children aged 6 to 12 years, by age and area, 2011-2012

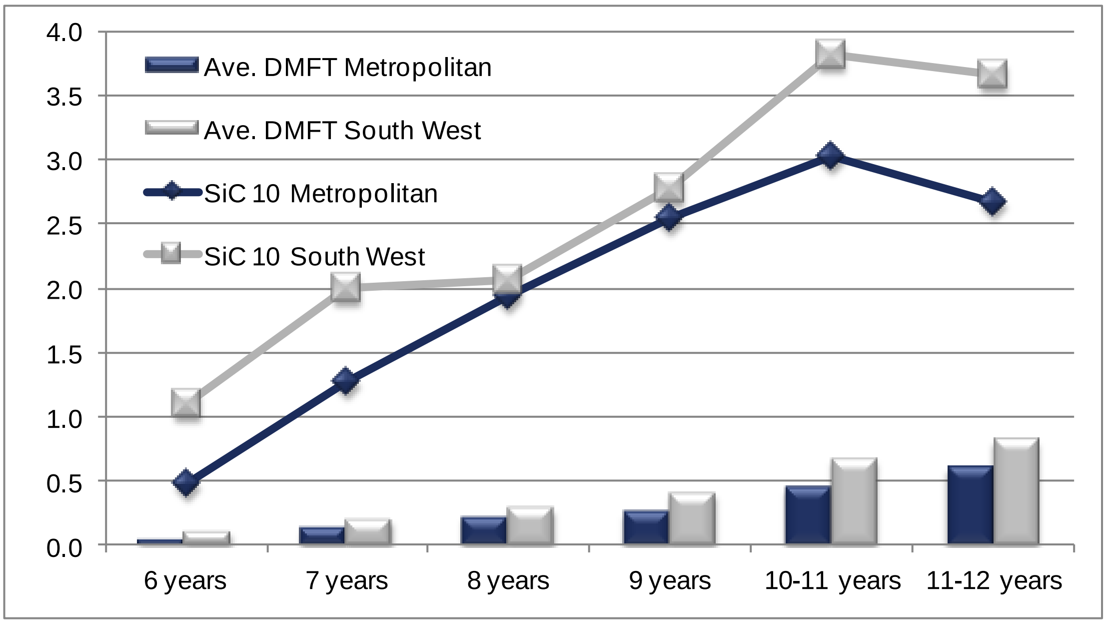
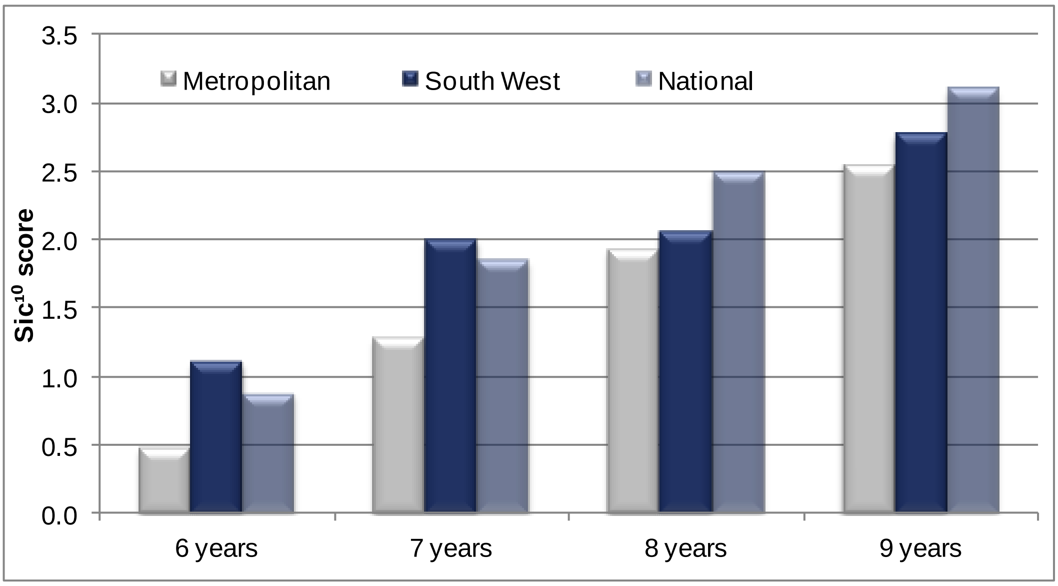


Figure 10 shows SiC[10] scores for permanent teeth (DMFT) for children aged 6 to 9 years from the metropolitan area and South West of WA (2011-2012) and national SiC[10] scores from the 2007 National Dental Health Survey. Overall, SiC[10] scores for children from the metropolitan area and South West of WA were lower than the national averages, excluding SiC[10] scores for children aged 6 to 7 years from the South West of WA, which were a little higher than the national averages.

Figure 10: SiC[10] scores, permanent teeth, children aged 6 to 9 years, metropolitan, South West (2011-2012) and national (2007)



Note: National data obtained from Mejia et al, 2012

Factors influencing one or more decayed, missing or filled deciduous teeth

A multivariate logistic regression model was constructed to assess whether there was an association between area of residence and having one or more decayed, missing or filled deciduous teeth among children aged 5 to 9 years. After univariate analysis (results not shown), age, sex, Aboriginal status and having a record of an initial examination at a DTC were included as control variables. Table 12 presents the results.

Children from the South West of WA had 1.5 times the odds of having one or more decayed, missing or filled deciduous teeth compared with their counterparts from the Perth metropolitan area after controlling for the effects of age, sex, Aboriginal status and having a record of an initial examination at a DTC (Table 12).

After adjusting for the control variables, the odds of having one or more decayed, missing or filled deciduous teeth increased by a factor of 1.2 for every additional year in age from 5 to 9 years. The adjusted decrease in odds of experience one or more decayed, missing or filled deciduous teeth associated with an initial examination at a DTC was 0.9. Aboriginal children had over four times the odds (OR 4.34) of having one or more decayed, missing or filled deciduous teeth compared to non-Aboriginal children.

Table 12: Results for the binomial logistic regression to estimate the effect of area on the likelihood of one or more decayed, missing or filled deciduous teeth for children aged 5 to 9 years, 2011-2012

Factor	Multivariate analysis		
	OR	95% CI	p-value
Age in years	1.20	(1.70 - 1.24)	0.000
Male gender	1.02	(0.95 - 1.09)	0.652
Aboriginal	4.34	(3.56 - 5.28)	0.000
Aboriginal status unknown	1.35	(1.03 - 1.78)	0.030
Initial examination at a DTC	0.90	(0.82 - 0.98)	0.020
South West area (ref Metro)	1.54	(1.35 - 1.75)	0.000

Factors influencing one or more decayed, missing or filled permanent teeth

A multivariate logistic regression model was constructed to assess whether there was an association between area of residence and having one or more decayed, missing or filled permanent teeth among children aged 6 to 12 years. After univariate analysis (results not shown), age, sex, Aboriginal status and having a record of an initial examination at a DTC were included as control variables. Table 13 presents the results.

Children from the South West of WA had 1.6 times the odds of having one or more decayed, missing or filled deciduous teeth compared with their counterparts from the Perth metropolitan area after controlling for the effects of age, sex, Aboriginal status and having a record of an initial examination at a DTC.

After adjusting for the control variables, the odds of having one or more decayed, missing or filled permanent teeth increased by factor of 1.45 for every additional year in age from 6 to 12 years. Aboriginal children had almost two and a half times the odds (OR=2.41) of having one or more decayed, missing or filled permanent teeth compared to non-Aboriginal children. No other factors were statistically significant.

Table 13: Results for the binomial logistic regression to estimate the effect of area on the likelihood of one or more decayed, missing or filled permanent teeth for children aged 6 to 12 years, 2011-2012

Factor	Multivariate analysis		
	OR	95% CI	p-value
Age in years	1.45	(1.41 - 1.50)	<0.001
Male gender	0.89	(0.79 - 1.00)	0.055
Aboriginal	2.41	(1.77 - 3.29)	<0.001
Aboriginal status unknown	1.19	(0.79 - 1.80)	0.411
Initial examination at a DTC	1.08	(0.90 - 1.30)	0.396
South West area (ref Metro)	1.62	(1.33 - 1.98)	<0.001

Discussion

Summary of findings

The study found that children from non-fluoridated areas (South West) had poorer dental health outcomes than children from fluoridated areas (metropolitan) in WA, including a higher proportion of deciduous and permanent tooth decay, even after adjusting for potential confounders.

Higher proportions of one or more decayed, missing or filled deciduous teeth were found in children from the South West of WA compared with the metropolitan area, particularly for children aged 5 and 7 years. Average total numbers of decayed, missing and filled deciduous teeth were also significantly higher for children aged 5 years from the South West of WA compared with the metropolitan area. The significant caries index (10%) scores for deciduous teeth were consistently higher for children from the South West of WA compared to the metropolitan area at all ages from 5 to 9 years, although both areas recorded scores lower than the national average.

The proportion of permanent tooth decay was also higher among children from the South West of WA compared with the metropolitan area, in particular for children aged 9 to 12 years. The average total number of filled permanent teeth was higher for children from the South West of WA compared with the metropolitan area in particular for those aged 7, 9 and 10 to 11 years. The significant caries index (10%) scores for permanent teeth were consistently higher for children from the South West of WA compared to the metropolitan area at all ages from 6 to 9 years, and children aged 6 to 7 in the South West of WA recorded scores higher than the national average.

These findings persisted even after adjusting for age, sex, Aboriginal status and having an initial examination at a DTC. The adjusted increase in odds of having one or more decayed, missing or filled deciduous teeth due to residence in the South West of WA was 1.5 and the adjusted increase in odds of having one or more decayed, missing or filled permanent teeth due to residence in the South West of WA was 1.6.

These findings are consistent with a number of Australian studies which found that fluoride exposure was associated with a reduced risk of dental caries [(Armfield et al, 2013), (Laurence et al, 2012), (Evans et al, 2009), (Do et al, 2009), (Spencer et al, 1996), (Armfield et al, 2005), (Slade et al, 1996)].

Limitations

Several limitations have been identified that are inherently associated with the cross-sectional study design which focused on area-level comparisons.

First, there was the potential for misclassification of cases as it is unknown how long children have resided in the area where they attended dental services. However, unless there has been a higher net movement of children from metropolitan to the South West of WA, then this effect should only weaken the strength of the association between non-fluoridation and caries experience.

The study controlled for age, sex, Aboriginal status and having an initial examination at a DTC but was unable to control for the effects of other individual level factors which may contribute to the risk of caries, including socio-economic status, diet, and dental and oral hygiene. However, previous research has shown that fluoridation continues to have a positive influence on dental outcomes after simultaneously controlling for these types of factors. For example Armfield et al (2013), conducted a study on the effect of sugar sweetened beverage (SSB) consumption and fluoridation on dental caries outcomes. The study found that while there was a dose related association between SSB consumption and increased dental caries occurrence, exposure to fluoridated water reduced this association. Of significance, there was no association between SSB consumption and caries in the permanent teeth of children aged 11 to 16 years who had resided in areas with optimum levels of fluoridation for more than half of their lives. Spencer et al (2008) also found that water fluoridation retained its significance as a predictor for permanent tooth caries after controlling for age, gender, other fluorides and socio-economic indicators.

It should also be noted that the sample size for individual ages in the South West of WA may have limited the power of the descriptive statistics to detect other small differences between the two groups as statistically significant.

Conclusion

Children living in non-fluoridated areas (South West) had poorer dental health than children from fluoridated areas (metropolitan) in WA, and this finding persisted even when age, sex, and Aboriginal status were accounted for. Despite some limitations in the study design, these findings are consistent with previous Australian studies and suggest that there is a protective effect associated with fluoride in drinking water.

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