



Fluoride exposure, dental fluorosis and caries among South Australian children

Loc Do

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Background

- Dental fluorosis-a potential side effect of fluoride use in prevention of caries
- In a population, fluorosis serves as “canary in the coal mine” to alert the public and the professional of potential over-exposure of fluoride

- Historically, fluoride in water was the only main source of fluoride
- The prevalence of fluorosis was, therefore, directly related with fluoride level in water
- The prevalence of fluorosis was relatively low in both optimal (1 ppm) and low-in-fluoride areas.

- A variety of discretionary fluorides have become available since the 1970s
- The prevalence of fluorosis increased rapidly during the 70s and 80s in western countries, with minimum and maximum prevalence ranging from
 - 4.4% to 55.0% in non-fluoridated areas
 - 11.4% to 80.9% in fluoridated areas

Source: *Roger 1999*
York Report 2000

Risk for fluorosis

- The main risk factors for fluorosis in the 80s and 90s were:
 - Fluoride in water
 - Fluoride from toothpaste
 - Fluoride supplements
 - Infant formula

Source: Maskarenhas & Burt 1998

Fluorosis in Australia in the 90s

- The prevalence of fluorosis in Australian children reached above that expected from water fluoridation alone

Area		Fluorosis prevalence
		1990
Western Australia	F	40.2%
	Non-F	33.0%
		1993
South Australia	F	48.7%
	Non-F	30.3%

WA: Riordan, 1991
SA: Puzio et al., 1993

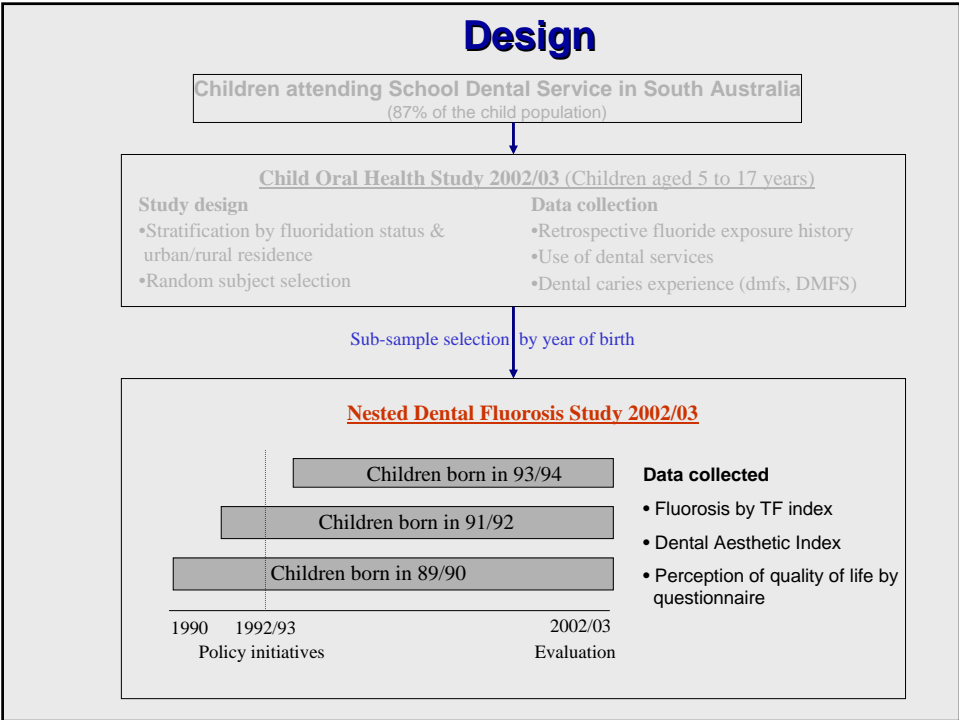
Representative for the SA child's population

Policy recommendations to control fluoride exposure in Australia in the early 1990s

- Low concentration fluoride toothpaste (400 to 550ppm F) for children's use
- Use of a pea-sized amount per brushing
- Delay toothpaste use until the age of 24 months
- Reduced fluoride supplement regimen
- Elimination of fluoride in infant formula powder

The Fluorosis Study 2002/03

- To report patterns of dental fluorosis among South Australian children
 - prevalence and severity
 - trend
 - risk factors
- To investigate risk and benefit balance of fluoride exposures
- To evaluate Oral Health-related Quality of Life of children and their parent in relation to fluorosis and caries experience



Data collection

Clinical examination at local SDS clinics
by a single dentist

- Dental fluorosis:
 - Thylstrup & Fejerskov (TF) Index
- Case definitions
 - TF score of 1+ on maxillary central incisors
 - TF score of 2+ on maxillary central incisors

Exposure to fluoride in water

- Data weighted to represent the state's child population
- Per cent of lifetime exposure to fluoride in water:
 - Birth to age 6 years

$$\text{Lifetime Exposure} = \sum_{\text{Age}=0}^{6 \text{ years}} [\text{Time in a locality}] \times [F^-] \times [\% \text{ public water consumed}]$$

Exposure to discretionary fluoride in early childhood

- Patterns of toothbrushing practice when toothpaste use began
 - Age when toothpaste use began
 - Type of toothpaste
 - Frequency of brushing per day
 - Amount of toothpaste used
 - Eating/licking toothpaste
- Use of fluoride supplement and infant formula in childhood

Study sample's characteristics

	Born 89/90	Born 91/92	Born 93/94	Total (col %)
Sex				
Boys	86 (50.3)	117 (52.2)	146 (51.8)	349 (51.6)
Girls	85 (49.7)	107 (47.8)	136 (48.2)	328 (48.4)
Current residency				
Adelaide	75 (43.9)	95 (42.4)	129 (45.7)	299 (44.2)
Other areas	96 (56.1)	129 (57.6)	153 (54.3)	378 (55.8)
Total (row %)	171 (25.3)	224 (33.1)	282 (41.7)	677 (100)

Chi-square, p>0.05

Other areas: Mount Gambier, Kingscote and Bordertown

Exposure to fluoride in water

	Exposure to fluoride in water: birth to 6 years (weighed %)		
	0% lifetime	>0 & ≤50% lifetime	>50% lifetime
Total (n=627)	26.2	41.6	32.2
Current residency			
Adelaide	* 9.5	48.9	41.6
Other areas	73.8	20.9	5.3
Birth cohort			
Born 89/90	28.4	38.5	33.1
Born 91/92	24.9	41.5	33.6
Born 93/94	25.3	44.6	30.2

* Chi-square p<0.01

Toothbrushing practice when toothbrushing started

	Birth cohorts (n, %)			P-value
	Born 89/90	Born 91/92	Born 93/94	
Started using toothpaste ≤24 m	76.6	67.3	75.2	0.090
Use children's low F toothpaste	28.2	74.5	82.9	<0.001
Brushed tooth 2+ times/day	39.4	41.5	39.4	0.879
Used a smear amount of toothpaste	68.6	66.2	70.2	0.711
Eating and/or licking toothpaste	49.4	42.7	54.6	0.047

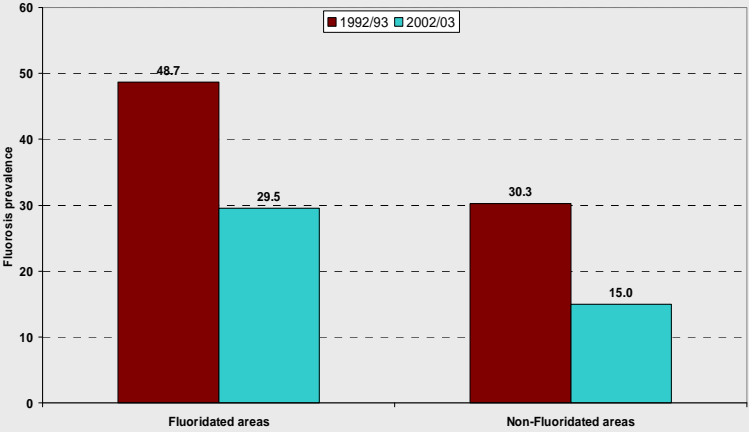
Patterns of dental fluorosis among South Australian children 2002/03

Distribution of fluorosis severity

TF score	Residency *		Total
	F area	Non F area	
TF 0	211 (70.5)	321 (85.0)	532 (74.3)
TF 1	49 (16.0)	39 (10.1)	88 (14.4)
TF 2	32 (11.4)	15 (3.7)	47 (9.5)
TF 3	7 (2.1)	3 (1.2)	10 (1.8)

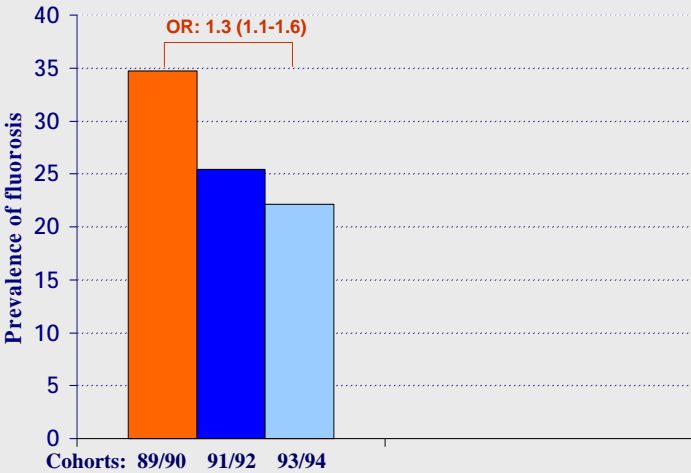
Fluorosis on maxillary central incisors
* Chi-square, $p < 0.05$

Time trend of fluorosis: 1990s to 2000s



Data represented the SA child population in 1993 and 2003

Inter-cohort trend of fluorosis Case definition: TF 1+



Having a TF 1+

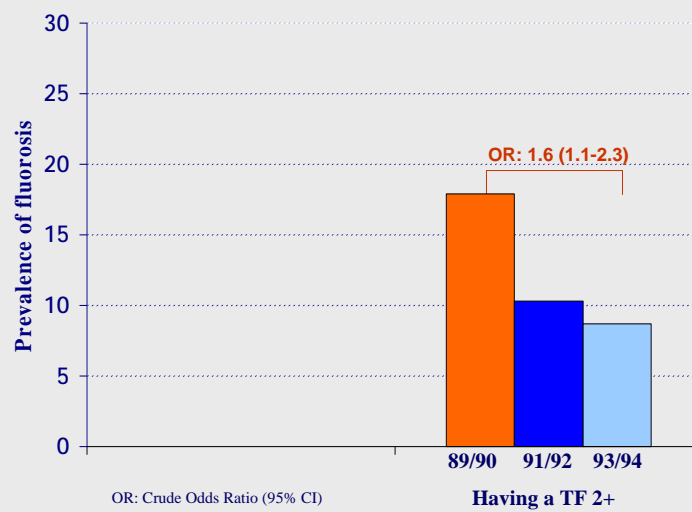
OR: Crude Odds Ratio (95% CI)

Risk factors for fluorosis Case definition: TF 1+

Explanatory variables	Odds Ratio (95% CI)
Lifetime exposure to F, birth to age six	
50% < lifetime	** 2.89 (1.54-5.42)
0 < and ≤ 50% lifetime	* 2.83 (1.47-5.55)
0% lifetime	Ref
Amount of toothpaste when brushing started	
Medium amount or larger	* 1.79 (1.08-2.98)
Small amount	Ref
Eating/licking toothpaste when brushing started	
Yes	** 2.61 (1.52-4.48)
No	Ref

Fluorosis defined as having a TF score of 1+ on the central incisors
 ns: p>0.05; * : p<0.05; ** : p<0.01
 Other non-significant factors are not listed

Inter-cohort trend of fluorosis Case definition: TF 2+



Risk factors for fluorosis

Case definition: TF 2+

Explanatory variables	Odds Ratio (95% CI)
Lifetime exposure to F, birth to age six	
50%< lifetime	** 7.81 (2.44-24.96)
0< and ≤50% lifetime	* 5.22 (1.56-17.42)
0% lifetime	Ref
Type of toothpaste when brushing started	
Standard F toothpaste	**2.70 (1.37-5.34)
Low F toothpaste	Ref
Eating/licking toothpaste when brushing started	
Yes	* 2.27 (1.03-5.03)
No	Ref

Fluorosis defined as having a TF score of 2+ on the central incisors
 ns: p>0.05; * : p<0.05; ** : p<0.001
 Other non-significant factors are not listed

- Fluorosis experience in this population was mostly very mild to mild
- There was a significant decreasing trend in the prevalence of fluorosis in the South Australian child's population
- The inter-cohort change in the prevalence of fluorosis seemed best explained by the increased used of low fluoride children's toothpaste

- Exposure to fluoride in water and toothpaste were the main risk factors for fluorosis
- Eating and/or licking toothpaste habit was highly prevalent
- Eliminating this habit could prevent more than a third of fluorosis cases

- There was a strong evidence of a declining trend of the prevalence of fluorosis among South Australian children
- The prevalence of fluorosis was found to be sensitive to change in exposure to discretionary fluoride in early childhood

Risk and benefit balance of fluoride exposures

The early use of fluoride

- Exposure to fluoride in early childhood can have a two-way impact:
 - Increased caries protection (benefit/protective)
 - Increased chance of fluorosis (risk/hazardous)

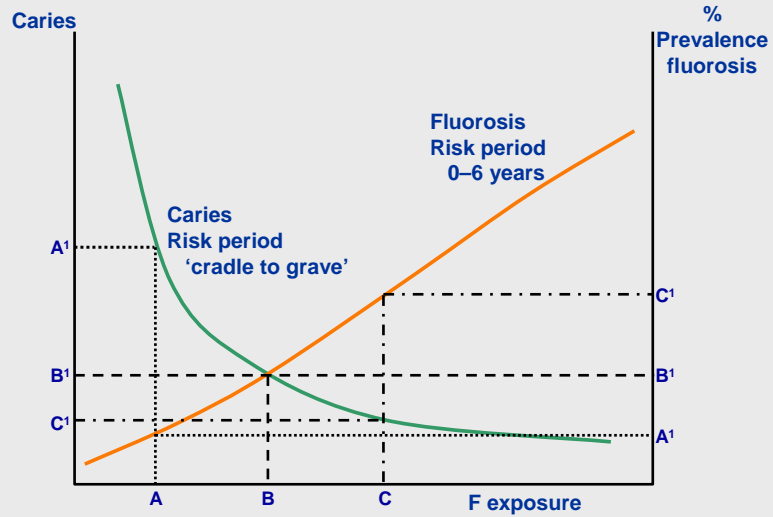
Benefit of early exposure to fluoride

- Early exposure to fluoride protects newly emerged primary teeth
- Healthy primary dentition provides a “biologically friendly” environment for the permanent dentition

Risk of early exposure to fluoride

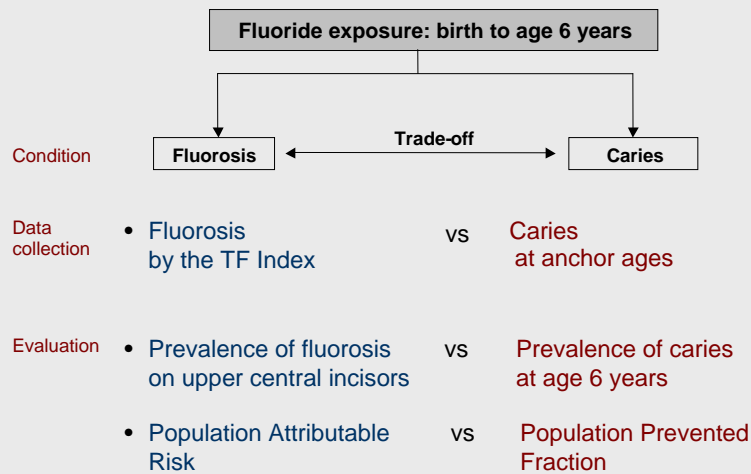
- A proportion of young children may have high intake of fluoride that leads to higher risk of fluorosis
- Through its aesthetic impact, fluorosis can affect the public perception of fluoride use

Figure The conceptual relationship between fluoride exposure, fluorosis and caries experience



Spencer 2006

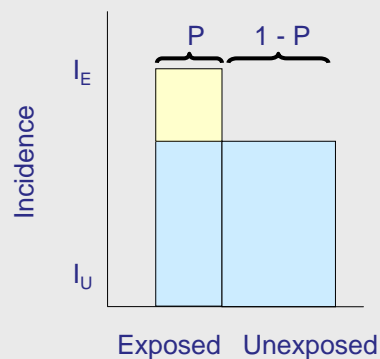
Evaluation



Population Attributable Risk (PAR)

- If relative risk > 1

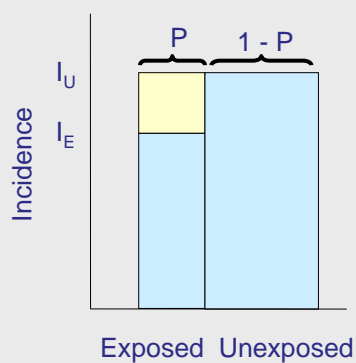
- Proportion of potential cases which would have not occurred if the exposure had been absent
- Proportion of potential cases prevented by eliminating the exposure



Population Prevented Fraction (PPF)

- If relative risk < 1

- Proportion of potential new cases which would have occurred if the exposure had been absent
- Proportion of potential cases prevented by the exposure



Estimating potential impact

- PAR and PPF calculations use incidence rates to estimate relative risk
 - Fluorosis: prevalence = incidence
 - Prevalence of deciduous caries at age 6y = incidence
 - Mean dmfs scores at anchor ages
- Bruzzi et al. (1982) proposed a method of calculating PAR & PPF from estimates of logistic regression model for incidence

Exposure to F in water: fluorosis and caries

Exposure to fluoride in water, birth to age 6 years	Prevalence of fluorosis ^a		Deciduous caries experience ^b	
	TF score 1+	TF score 2+	At age six	At age eight
0% lifetime	* 14.6	* 3.4	† 2.19 (4.06)	† 3.53 (5.09)
>0 & ≤50% lifetime	26.8	10.9	# 1.71 (3.43)	# 3.00 (5.18)
>50% lifetime	33.7	14.0	†# 0.94 (2.34)	†# 1.65 (3.16)

^a Defined as having one or more upper central incisors with a TF score 1+ or 2+;

* Chi-square, p<0.01

^b Mean deciduous dmfs at different ages, (SD in bracket)

† # One-way ANOVA, Tukey's posthoc test: statistically significant by pair; column comparison

Exposure to F in toothpaste: fluorosis and caries

<i>Age when toothpaste use started</i>	Prevalence of fluorosis ^a		Deciduous caries experience ^b	
	TF score 1+	TF score 2+	At age six	At age eight
≤18 months	* 31.8 ↑	* 13.2 ↑	† 1.03 (2.48)	† 1.85 (3.58) ↓
From 19 to 30 months	25.8	12.2	# 1.13 (2.60) ↓	2.32 (3.79)
After 30 th months	22.5	7.8	† # 2.04 (4.00)	† 3.20 (5.82)

^a Defined as having one or more upper central incisors with a TF score 1+ or 2+;

* Chi-square, p<0.01

^b Mean deciduous dmfs at different ages, (SD in bracket)

† # One-way ANOVA, Tukey's posthoc test: statistically significant by pair; column comparison

Exposure to F in toothpaste: fluorosis and caries

<i>Type of toothpaste used when brushing started</i>	Prevalence of fluorosis ^a		Deciduous caries experience ^b	
	TF score 1+	TF score 2+	At age six	At age eight
Standard F toothpaste	* 31.8 ↑	* 16.2 ↑	1.05 (2.82)	2.52 (5.52)
Children low F toothpaste	23.4	6.4	1.47 (3.08)	2.35 (3.93)

<i>Brushing frequency when brushing started</i>	Prevalence of fluorosis ^a		Deciduous caries experience ^b	
	TF score 1+	TF score 2+	At age six	At age eight
Twice a day or more	28.9	11.0	† 1.11 (2.81)	2.33 (4.68)
Once a day or less	24.7	11.1	† 1.53 (3.15) ↓	2.44 (4.14)

^a Defined as having one or more upper central incisors with a TF score 1+ or 2+;

* Chi-square, p<0.01

^b Mean deciduous dmfs at different ages, (SD in bracket)

† # One-way ANOVA, Tukey's posthoc test: statistically significant by pair; column comparison

Exposure to F in toothpaste: fluorosis and caries

<i>After-brushing routine when brushing started</i>	Prevalence of fluorosis ^a		Deciduous caries experience ^b	
	TF score 1+	TF score 2+	At age six	At age eight
Swallowed	29.1	13.0	1.28 (2.88)	2.52 (4.41)
Rinsed and spat out	26.6	10.3	1.78 (3.67)	2.84 (4.08)

<i>Toothpaste amount when brushing started</i>	Prevalence of fluorosis ^a		Deciduous caries experience ^b	
	TF score 1+	TF score 2+	At age six	At age eight
Pea size or larger	* 34.2 ↑	10.6	1.39 (2.87)	2.64 (4.06)
Smear amount	24.5	13.4	1.78 (3.96)	3.01 (5.64)

<i>Eating and/or licking toothpaste habit when brushing started</i>	Prevalence of fluorosis ^a		Deciduous caries experience ^b	
	TF score 1+	TF score 2+	At age six	At age eight
Yes	* 33.3 ↑	* 14.5 ↑	1.36 (2.95)	2.39 (4.01)
No	22.5	8.7	1.35 (3.08)	2.37 (4.63)

^a Defined as having one or more upper central incisors with a TF score 1+ or 2+;

* Chi-square, p<0.01

^b Mean deciduous dmfs at different ages, (SD in bracket)

† # One-way ANOVA, Tukey's posthoc test: statistically significant by pair; column comparison

Logistic regression models for fluorosis and caries

Explanatory factors	Logistic regression models	
	Fluorosis ^a	Caries ^b
<i>Lifetime exposure to fluoridated water birth to age 6 years</i>		
>50% lifetime	** 7.26 (2.52–20.93)	** 0.35 (0.21–0.60)
>0 and ≤50% lifetime	* 4.63 (1.56–13.79)	* 0.52 (0.31–0.89)
0% lifetime	Ref	Ref
<i>Age when toothpaste use started</i>		
Before 18 months	^{ns} 1.40 (0.84–2.34)	^{ns} 0.97 (0.51–1.85)
After 30th month	^{ns} 0.90 (0.38–2.11)	* 2.43 (1.36–4.34)
19 to 30 months	Ref	Ref
<i>Toothpaste when brushing started</i>		
1000-ppm fluoride toothpaste	* 2.70 (1.37–5.34)	^{ns} 0.84 (0.53–1.33)
<550-ppm fluoride toothpaste	Ref	Ref
<i>Eating, licking toothpaste habit</i>		
Yes	* 2.27 (1.03–5.03)	^{ns} 1.23 (0.78–1.95)
No	Ref	Ref

^a Logistic regression model for the prevalence of fluorosis defined as having a TF score of 2+ on maxillary central incisors (pseudo R²: 0.176)

^b Logistic regression model for the prevalence of deciduous caries at age 6 years (pseudo R²: 0.110)

^{ns} p>0.05; * p<0.05; ** p<0.001

Other factors in the models: sex, birth cohorts, amount of toothpaste, frequency of brushing, fluoride supplements, infant formula use.

PAR and PPF of exposures to fluoride

	Fluorosis		Caries	
	PAR ^a	Potential change ^b	PPF ^c	Potential change ^d
Exposed to fluoride in water until age 6 years	53 (23, 66)	60	36 (21, 46)	116
Ate and/or licked toothpaste when brushing started	36 (3, 50)	41	-12 (-47, 11)	-
Used a pea-sized or more when brushing started	13 (-6, 23)	-	1 (-17, 13)	-
Used 1000-ppm F toothpaste when brushing started	22 (9, 29)	25	3 (-15, 15)	-
Commencing toothpaste use before 31 months	5 (-63, 36)	-	36 (13, 50)	116
Brushing frequency	11 (-32, 34)	-	1 (-16, 12)	-
Swallowing after brushing	28 (-36, 34)	-	24 (-1, 34)	-

PAR and PPF derived from logistic regression models; therefore are not additive

Fluorosis: Prevalence of fluorosis defined as having a TF score of 2+ on upper central incisors

Caries: Prevalence of caries at age 6 years

^a Population Attributable Risk (95% CI): Proportion of cases attributed to exposure

^b Number of cases per 1000 children having a TF score of 2+ potentially reduced were the exposure modified or eliminated, given the population prevalence of 11.3%.

^c Population Prevented Fraction (95% CI): Proportion of cases prevented by exposure

^d Number of cases per 1000 children with caries at age 6 years potentially increased were the exposure modified or eliminated, given the population prevalence of 32.3%

Discussion

- It is important to maintain the working balance of all proven effective fluoride delivery methods
- Simultaneous evaluation of caries and fluorosis is a measure of impact of an fluoride exposure

Exposure to fluoride in water

- Exposure to fluoride in water showed the strong two-way relationship with fluorosis and caries
- Modifying this exposure could have potentially significant impact on both fluorosis and caries

Age of commencement of toothpaste use

- Early initiation of tooth cleaning can be beneficial
- Early toothpaste use (before 18 months) and late toothpaste use (after 30 months) may not be effective or safe
- The age of toothpaste commencement can vary depending on other risk and protective factors

Type of toothpaste

- Low concentration fluoride toothpaste reduces risk of fluorosis when used among young children
- The protective effect of 400-550-ppm fluoride toothpaste needs further investigation
- No evidence a lack of equivalency of 400-550-ppm F with standard concentration fluoride toothpaste

Eating/licking toothpaste

- Eating/licking toothpaste habit had only hazardous impact
- Preventing this habit could significantly reduce risk of toothpaste use without effect on caries protection

Oral Health-related Quality of Life of South Australian children

Methods

- Children and their parent completed a self-administered questionnaire:
 - Child Perception Questionnaire CPQ₈₋₁₀ for 8-10-yo
 - Child Perception Questionnaire CPQ₁₁₋₁₄ for 11-13-yo
 - Parental Perception Questionnaire (PPQ)

Global ratings of oral health

- Children & parents rated their (their child's) oral health using a 5-point Likert scale

Q: How would you rate the health of your (your child's) teeth, lips, jaws and mouth?

A: Excellent=1; Very good=2; Good=3; Average=4; Poor=5

- Good Oral health = Excellent or Very good

Oral Health Related Quality of Life

- OHRQoL items addressed impact of oral health in the last 3 months (for CPQ₁₁₋₁₄ and PPQ) and the last 4 weeks for CPQ₈₋₁₀
- 5-point Likert scale was used for all items

Example: During the last 3 months, How often have you had?
Pain in the teeth, lips jaws or mouth?

Never=0; Hardly ever=1; Sometimes=2; Often=3; Very Often =4

- OHRQoL score = sum of responses
- Higher score indicates poorer OHRQoL

Caries and fluorosis classifications

- Caries experience (deciduous and permanent) at the time of the study was used to categorise children
- Fluorosis experience assessed as the highest score by the TF Index on maxillary incisors (maximum four teeth)

	Caries	Fluorosis *
None:	0 surface	TF 0
Low:	1–2 surfaces	TF 1
Moderate:	3–4 surfaces	TF 2
Severe:	5+ surfaces	TF 3

* Highest observed fluorosis score was TF 3

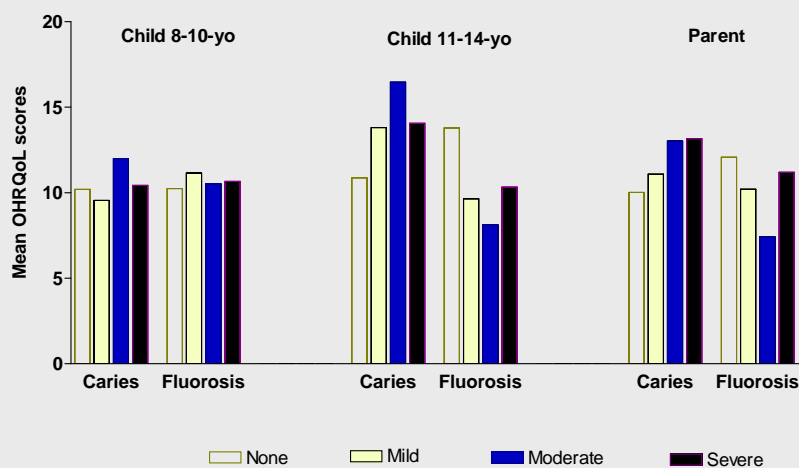
Dental Aesthetic Index

- 10 occlusal traits were recorded to calculate Dental Aesthetic Index (DAI) score
- The higher DAI score the less socially acceptable occlusion
- Children were dichotomised:
 - Acceptable occlusion: DAI: 13 to 32
 - Less acceptable occlusion: DAI: 33+

Respondents

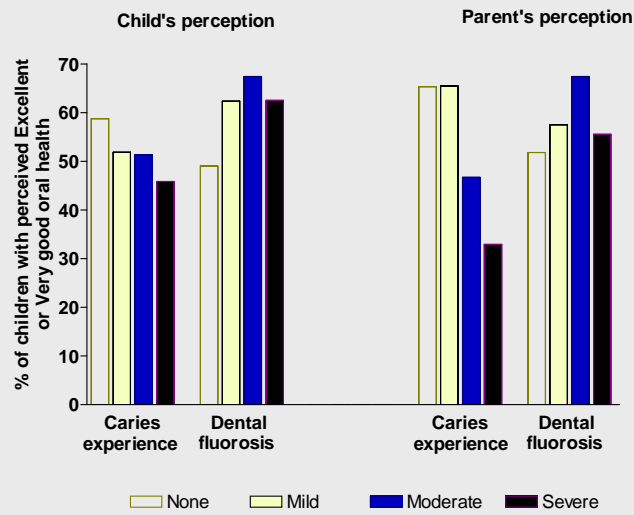
	CPQ ₈₋₁₀	CPQ ₁₁₋₁₄	PPQ	
N of responses	374	468	842	
Caries experience	None	Low	Moderate	Severe
n (%)	246 (42.3)	141 (21.7)	76 (12.1)	170 (23.9)
Fluorosis experience	None	Low	Moderate	Severe
n (%)	499 (71.8)	97 (16.1)	49 (10.1)	11 (2.0)
DAI	Acceptable occlusion		Less acceptable occlusion	
n (%)	492 (75.9)		177 (24.1)	

ORHRQoL scores by caries and fluorosis experience



Higher mean indicates poorer OHRQoL

Global rating of oral health



Factors for perceiving Good oral health

	Child' perception	
	Odds ratio (95% CI)	P
Caries experience		
None	Ref	
Low (1-2 surfaces)	0.73 (0.47-1.15)	0.18
Moderate (3-4 surfaces)	1.01 (0.57-1.77)	0.98
Severe (5+ surfaces)	0.71 (0.44-1.15)	0.16
Fluorosis experience		
None	Ref	
Low (TF 1)	1.38 (0.87-2.19)	0.17
Moderate (TF2)	1.87 (1.00-3.48)	0.05
Severe (TF 3)	1.20 (0.28-5.10)	0.80
DAI score		
Acceptable occlusion (DAI≤32)	Ref	
Less acceptable occlusion (DAI:33+)	0.57 (0.38-0.87)	0.01

Global Rating of Oral Health: Excellent or Very good
Other variables in the model: Age, Sex, Residency, Parental education, Household income

Factors for perceiving Good oral health

	Child' perception		Parent's perception	
	Odds ratio (95% CI)	P	Odds ratio (95% CI)	P
Caries experience				
None	Ref		Ref	
Low (1-2 surfaces)	0.73 (0.47-1.15)	0.18	1.11 (0.70-1.78)	0.65
Moderate (3-4 surfaces)	1.01 (0.57-1.77)	0.98	0.79 (0.45-1.41)	0.43
Severe (5+ surfaces)	0.71 (0.44-1.15)	0.16	0.32 (0.19-0.53)	0.00
Fluorosis experience				
None	Ref		Ref	
Low (TF 1)	1.38 (0.87-2.19)	0.17	1.09 (0.68-1.74)	0.73
Moderate (TF2)	1.87 (1.00-3.48)	0.05	1.65 (0.85-3.21)	0.14
Severe (TF 3)	1.20 (0.28-5.10)	0.80	0.66 (0.15-2.85)	0.58
DAI score				
Acceptable occlusion (DAI≤32)	Ref		Ref	
Less acceptable occlusion (DAI:33+)	0.57 (0.38-0.87)	0.01	0.60 (0.39-0.92)	0.02

Global Rating of Oral Health: Excellent or Very good
Other variables in the model: Age, Sex, Residency, Parental education, Household income

- Dental fluorosis and caries have measurable impact on affected children and their parent
- The impact can be measured

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