Risk factors for dental fluorosis: A review of the recent literature

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Abstract

The decline in dental caries prevalence and incidence in developed countries over the last two decades is considered to be largely due to the widespread use of fluoride. Simultaneously, with the decline in caries, an increase in the prevalence of dental fluorosis has been noticed. The increase is in the mild and very mild forms of fluorosis, and is proportionally greater in non-fluoridated areas than in fluoridated areas. This is because of the increase in the mean fluoride intake from all sources since the 1940s. The increase in fluorosis prevalence prompted numerous studies on risk factors for fluorosis. As a result the literature over the last two decades has also reported numerous studies with differing and confusing results. This paper describes for the clinician the condition and summarizes the recent literature on the risk factors for fluorosis. Only well conducted studies evaluating risk factors or indicators and quantifying the risk for dental fluorosis from the 1980s through the1990s time period were included in this review. Four major risk factors were consistently identified: use of fluoridated drinking water, fluoride supplements, fluoride toothpaste, and infant formulas before the age of six years. (Pediatr Dent 22:269-277, 2000)

There has been a decline in dental caries prevalence and incidence in the developed countries over the last two decades. This decrease is considered to be largely due to the widespread use of fluoride. Concurrent with the decline in caries, an increase in the prevalence of dental fluorosis has been noticed (Table 1). Concern with the increase in the prevalence has led to numerous studies on reasons for the increase, and in identifying the risk factors for fluorosis. Consequently, the literature has seen a substantial number of studies reported. These studies employing various study designs have used different populations, many with multiple sources of fluoride, and differing indices to measure fluorosis. As a result the conclusions of some of these studies are not similar, and in some cases even contradictory and confusing. The purpose of this paper is to summarize for the clinician the recent literature on risk factors for fluorosis.

"Dental fluorosis," a specific disturbance in tooth formation and an esthetic condition, is defined as a chronic, fluoride-induced condition, in which enamel development is disrupted and the enamel is hypomineralized.[16] Simply put, dental fluorosis is a condition in which an excess of fluoride is incorporated in the developing tooth enamel. A large amount of epidemiological data demonstrates that the occurrence of fluorosis lesions is associated with excessive fluoride intake during the period of tooth development.[5,15,17-20] The most important risk factor in determining fluorosis occurrence and severity is the total amount of fluoride consumed from all sources during the critical period of tooth development.[17,21] Fluorosis has a very characteristic appearance in terms of tooth surface appearance and distribution in the mouth.[16-19,22-24]

Microscopically, fluoride affects the forming enamel by making it more porous.[16] The degree and extent of the porosity depends on the concentration of fluoride in the tissue fluids during tooth development.[16,18] The structural arrangement of the crystals appears normal, but the width of the intercrystalline spaces is increased, causing pores. With increasing severity of fluorosis, the fluoride concentration throughout the enamel, the depth of enamel involvement, and the degree of porosity of the enamel also increases.[16,25] Clinical studies of dental fluorosis have demonstrated that the most critical period for development of fluorosis is during the post-secretory or early maturation phase of tooth development.[15,18,26-29] Since the different teeth are developing at different times, for the whole dentition, this critical period translates to a period from birth to age 8 in a child. For the aesthetically important teeth this period ranges from birth to age six.

Clinically, enamel fluorosis is seen as white spots, or white opaque lines or striations, or a white parchment-like appearance of the tooth surface. The brown stains sometimes seen in moderate to severe fluorosis are due to the uptake of extrinsic stains mainly from the diet. At higher concentrations of fluoride, discrete or confluent pitting of the enamel surface is seen, accompanied by extrinsic stains.[18] Fluorosis is symmetrically distributed, but the severity varies among the different types of teeth.[17-19,26,30] Teeth that develop and mineralize later in life such as premolars have a higher prevalence of fluorosis, and are more severely affected.[26,30,31]

It was believed that fluorosis was probable following intakes of 0.1 mg F/kg body weight during infancy,[32] although Roholm as early as 1937 had suggested that 0.07 mg F/kg body weight would cause macroscopic changes in teeth.[33] More recent evidence has put that threshold at 0.03 to 0.1 mg F/kg body weight for European children[34] or between approximately 0.75 and 1.0 mg/day.[35] Studies in Kenya have found fluorosis with a daily fluoride intake of less than 0.03 mg F/kg body weight from water.[30,31] Other factors that have been associated with susceptibility of populations to dental fluorosis are altitude,[36] renal insufficiency, and possibly malnutrition.

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Table 1. Dental Fluorosis Prevalence in North American Fluoridated and Non-Fluoridated Communities, and the Indices used in the study

Source	*Year of Publication*	*Age (Yr)*	*Sample Size*	*Water Fluoride Level (ppm)*	*Fluorosis Prevalence*	*Index*
Fluoridated						
Segreto et al.[1]	1984	7-19	361	1.0	39.4	Dean's
Driscoll et al.[2]	1986	8-16	336	optimal	14.6	Dean's
Leverett[3]	1986	12-14	553	1.0	25.5	Dean's
Heifetz et al.[4]	1988	8-10	111	optimal	28.1	TSIF
		13-15	94	optimal	29.4	
Szpunar and Burt[5]	1988	6-12	425	0.8	31.0	TSIF
				1.0	49.0	
				1.2	51.2	
Osuji et al.[6]	1988	8-10	633	1.0	12.9	TF
Kumar et al.[7]	1989	7-14	539	1.0	7.7	Dean's
Ismail et al.[8]	1990	11-17	437	1.0	55.0	TSIF
William and Zwermer	1990	12-14	157	0.9-1.2	80.9	TSIF
Ismail et al.[9]	1993	10-11	116	1.1	69.2	TSIF
Heller et al.[10]	1997	7-17	6,728	0.7-1.2	29.9	TSIF
Jackson et al.[12]	1999	7-14	122	1.0	58.0	TSIF
Nonfluoridated						
Segreto et al.[1]	1984	7-19	326	0.3	8.6	Dean's
Driscoll et al.[2]	1986	8-16	316	<0.3	2.9	Dean's
Leverett[3]	1986	12-14	251	<0.3	5.2	Dean's
Pendrys et al.[13]	1986	9-13	4,222	<0.3	25.2	Dean's
Szpunar and Burt[5]	1988	6-12	131	0.0	12.2	TSIF
Kumar et al.[7]	1989	7-14	510	<0.3	7.4	Dean's
Woolfolk et al.[14]	1989	9-13	412	-	22.0	TSIF
Pendrys and Katz.[15]	1989	11-14	850	<0.3	34.2	FRI
Ismail et al.[8]	1990	11-17	499	<0.1	31.0	TSIF
Ismail et al.[9]	1993	10-11	103	<0.1	41.5	TSIF
Heller et al.[10]	1997	7-17	6,239	<0.3	13.5	TSIF
Jackson et al.[12]	1999	7-14	124	0.2	42.0	TSIF

Risk factors for fluorosis

Studies on the prevalence of fluorosis in North America began in 1906 when McKay first observed a discoloration called the "Colorado Brown Stain,"[37] leading to the discovery of fluoride's caries preventive action. More recent epidemiological research in the 1980s and 1990s in North America has shown an increase in the prevalence of fluorosis (Table 1), particularly when compared to the studies by Dean and colleagues that occurred during the 1930s to mid 1950s.[5] This increase in prevalence is more noticeable in the fluoride deficient communities than

Table 2. Risk of Dental Fluorosis from Use of Fluoridated Drinking Water

Study	*Country*	*Water Fluoride Level (ppm)*	*Odds Ratio*	*95% CL**
Szpunar and Burt, 1988[5]	US	0.8	3.91	(1.98-7.73)
		1.0	8,46	(4.52-15.82)
		1.2	7.69	(1.35-37.89)
Ismail et al, 1990[8]	Canada	1.0	3.43	(3.30-17.91)
Riordan and Banks, 19913[45]	Australia	0.8	4.06	(1.97-10.9)
Riordan 1993[46]	Australia	0.8	4.88	(1.74-13.69)
Skotowski et al., 1995[57]	US	>0.7	3.97	(1.75-9.05)
Heller et al., 1997[10]	US	0.3-0.7	2.07	(0.92-4.67)
		0.7-1.2	3.32	(2.25-4.91
		>1.2	4.96	(2.87-8.58)
Kumar and Swango, 1999[58]	US	1.0	2.50	(1.50-3.90)

* CL=Confidence Limits

those with optimal or above optimal water fluoride concentrations,[3,7,8,11,38] and is principally in the milder forms, although there has been some increase in the more moderate forms.[4,38] Table 1 gives prevalence of dental fluorosis in North American fluoridated and non-fluoridated communities. Concern for the increase in the prevalence of dental fluorosis led to studies designed to identify the various risk factors for fluorosis. While a few studies were case-control in design, [5,6,15,39-42] most were cross-sectional in design.[14,43-46] The cross-sectional study design is not ideal for studying risk indicators or factors. Hence the use of this study design in some of the fluorosis literature is a major criticism. However, there have been substantially more case-control studies done in the 1990s, providing a higher level of evidence than in the 1980s. Another major criticism of all the fluorosis studies is the use of retrospective assessment of fluoride exposures, and the inherent recall bias in all the studies. It is expected however, that the recall bias is random, therefore not overly affecting the results. Another criticism of these studies is that the indices used in the different studies varied, from using fluorosis specific indices,[27,39,41,42,45-48] to those measuring all enamel defects.[49-52] The sensitivity of these indices in detecting fluorosis differs, leading to most of the disparity in the prevalence and risk estimates between the studies.

Some of the reasons that were postulated for the increase in the prevalence of fluorosis, particularly in fluoride-deficient communities is the widespread use of fluoride in both fluoridated and non-fluoridated communities since the 1940s, and what came to be called the "halo" effect. Although technically a community that does not have fluoride in its water supply is considered non-fluoridated, in reality its population has access to other sources of fluoride such as fluoride supplements, fluoride toothpaste, and fluoride in the food and beverages they consume. For example, over 95% of the population in developed countries use fluoride toothpaste,[44,53] and foods and beverages may be processed in fluoridated communities but are shipped, sold, and consumed in non-fluoridated communities.

The fluorosis studies, done in fluoridated and non-fluoridated areas, have identified four major risk factors: use of fluoridated drinking water, fluoride supplements, fluoride toothpaste, and infant formulas before the age of eight years. Only well conducted studies evaluating risk factors or indicators and quantifying the risk for dental fluorosis from the 1980s through the1990s time period are being included in this paper because of the increase in methodological sophistication in these papers compared to earlier studies.

Fluoridated drinking water

Dean, in his early studies recommending fluoridation of water, estimated a 10 percent prevalence of mild or very mild fluorosis in the permanent teeth at water fluoride levels of 1.0 ppm.[18] Reports 10 to 17 years after water fluoridation from the Newburgh-Kingston and Grand Rapids water fluoride studies showed that 7 to 16 percent of the children born and raised in the areas exhibited dental fluorosis.[54,55] This degree of prevalence was recorded when drinking water was virtually the only potential source of fluoride. In the US, prevalence of fluorosis in the mid-1980s, when fluoride was available from multiple sources, was 22.3 percent in a national sample of schoolchildren.[56] As seen in Table 1, the prevalence of fluorosis ranges from 7.7% to 69% in fluoridated communities, and from 2.9% to 42% in non-fluoridated communities. The later studies reported higher prevalence of fluorosis, and used only lifetime residents in the study.[9,12,40] These data are evidence of a substantial increase in the prevalence of fluorosis in North America.

Table 3. Risk of Dental Fluorosis from Use of Fluoride Supplements

Study	*Country*	*Sample Size*	*Odds Ratio*	*95% CL or P-value*
Fluoridated				
Kumar et al, 1989[7]	US	3,209	1.7	(-0.5-3.9)
Pendrys et al, 1994[39]	US	401	23.7	(3.43-164.3)
Pendrys and Katz, 1998[42]	US	233	10.8	(1.9-61.55)
Non-fluoridated				
Holm and Andersson, 1982[47]	Sweden	134	5.4	$P<0.001$
Bagramian et al, 1989[64]	US	206	2.01	(0.71-5.75)
Woolfolk et al, 1989[14]	US	412	3.08	$P<.01$
Pendrys and Katz, 1989[15]	US	850	4.0	(1.4-11.4)*
Kumar et al, 1989[7]	US	2,611	3.8	(0.07-6.9)
Holt et al, 1994[65]	UK	1,523	2.42	(1.48-3.97)
Lalumandier and Rozier 1995[41]	US	708	6.5	$P<0.001$
Pendrys et al, 1996[41]	US	460	7.97	(2.98-21.33)
Wang et al, 1997**[66]	Sweden	383	1.84	(1.28-6.92)
Jackson et al, 1999[12]	US	124	2.96	(1.43-2.35)
Kumar and Swango, 1999[58]	US	2,193	2.90	(1.30-4.70)
Fluoridated versus non-fluoridated				
Ismail et al, 1990[8]	Canada	936	1.7	(1.28-2.27)
Riordan and Banks, 1991[45]	Australia	659	4.63	(1.97-10.9)
Heller et al., 1997[10]	US	15,041	1.49	(1.11-1.99)

* 99% CL
** Odds ratio is for each additional year of regular supplement use

Table 2 reports the odds of fluorosis from use of fluoridated water in developed countries where populations have access to multiple sources of fluoride. The number of studies that looked at water fluoride content as a risk factor are fewer than those which examined the use of fluoride supplements or other risk factors. This is because the more recent studies, such as those by Pendrys and colleagues, evaluated the risk of fluorosis in fluoridated or non-fluoridated communities separately. The role of the water fluoride content in fluorosis could therefore not be evaluated. As seen from the table, across the different developed countries the odds ratios are relatively stable for a given water fluoride level, and the odds of fluorosis increased as the water fluoride content increased. For example, the studies by Szpunar and Burt, and Riordan are in agreement with the finding that the risk of fluorosis at 0.8 ppm F are four times higher than non-fluoridated communities.[5,45,46] These results are from logistic regression analyses that control for the other sources of fluoride. One study[59] showed an inverse association between drinking water fluoride level and fluorosis. This study, however, looked at a wide age range (6-14 years) of children. The teeth known to be most sensitive to developing fluorosis are the premolars and then the anterior teeth.[26,31,60,61] The younger children in this study could have been misclassified as not having fluorosis because these teeth had not erupted.

Fluoride supplements

Fluoride supplements are recommended for use in children in fluoride-deficient areas as a caries preventive measure. Numerous studies have shown that supplements are also prescribed to children in fluoridated areas, albeit inappropriately.[40,62,63] Table 3 reports the odds ratios from the many studies identifying fluoride supplements as a risk factor for fluorosis. These studies evaluated the role of supplements in fluoridated, non-fluoridated, and both fluoridated and non-fluoridated communities. The odds ratio for fluorosis from use of supplements in the fluoridated areas was as high as 24, while in the non-fluoridated areas where fluoride supplements are routinely recommended the odds ratios ranged from 1.7 to 8. In fluoridated areas, the risk of fluorosis from use of fluoride supplements is much higher, almost four times that in non-fluoridated areas. This is confirmed by those studies that compared fluoridated communities to non-fluoridated communities such as the well-designed and conducted study by Riordan and Banks[45] in Western Australia.

For the U.S. studies reported in Table 3, the supplement guidelines that were being followed were the older revised guidelines established in 1979. The increased risk of fluorosis demonstrated by the results of these studies caused a further revision of the fluoride supplement dosage in 1994 which was supported by the American Dental Association, American Academy of Pediatric Dentistry, and the American Academy of Pediatrics.[67,68] No studies yet have reported on the risk of fluorosis for children born after and supplemented using the 1994 supplement guidelines.[67] It is anticipated, however, that the risk will have reduced, compared to that seen in Table 3.

In summary, there is substantial evidence for the risk of fluorosis from use of supplements in fluoridated and non-fluoridated areas. To prevent fluorosis, it is recommended that before fluoride supplements are prescribed, clinicians should consider the fluoride content of the water consumed, and the caries risk of the child.

Infant formulas

Infant formulas in North America used to contain variable and high concentrations of fluoride,[69,70] until 1979 when the manufacturers of infant formula voluntarily reduced and controlled the concentration of fluoride in their products. Studies of risk factors for fluorosis (Table 4) involving children who were born before 1979 have shown infant formula to be a risk factor for fluorosis in fluoridated and non-fluoridated areas with statistically significant risk as high as seven times in the fluoridated areas.[6,15,39] However, concern continued that even after the reduction of fluoride content, infant formula was still a potential risk factor, particularly in fluoridated communities. Pendrys and colleagues then designed a series of studies to evaluate the risk of fluorosis in children born after 1979.[41,42] Results of these studies showed that in nonfluoridated communities, infant formula use was no longer a risk factor for fluorosis,[41] but in

Table 4. Risk of Dental Fluorosis from Use of Infant Formula

Study	*Country*	*Sample Size*	*Odds Ratio*	*95% CL or P-value*
Fluoridated				
Osuji et al, 1988••[6]	Canada	147	5.58	(2.24-13.92)
Pendrys et al., 1994••[39]	US	401	3.34[#]	(1.38-8.07)
			7.16[†]	(1.35-37.89)
Pendrys et al., 1998[$42]	US	233	10.77	(1.89-61.25)
Nonfluoridated				
Pendrys and Katz, 1989••[15]	US	850	1.7	(0.7-4.2)[•]
Fluoridated and nonfluoridated				
Clark et al., 1994[59]	Canada	1131	1.8	$P<0.02$

[•] 99% CL, [#] milk based, [†] soy based,
[••] Children born before 1979,
[$] Children born after 1979

the fluoridated areas it was still a significant risk factor with an odds ratio of 10.77 (95% CI 1.89-61.25). The authors conclude that taken together, these two studies show that the addition of optimally fluoridated water to concentrated infant formula containing relatively low fluoride may produce a liquid with an above optimum fluoride concentration, with the potential to contribute to the development of fluorosis.[42] Therefore, to reduce the risk of fluorosis from the use of infant formulas the recommendation would be to use ready-to feed formulas, or use non-fluoride containing bottled water to dilute formula concentrate.

Fluoride toothpaste

There has been substantial controversy in the literature on fluoride toothpaste's role in causing fluorosis. Ripa,[71] in a 1991 review of studies seeking an association between use of fluoride toothpaste and the prevalence of fluorosis, concluded that of the 10 studies reviewed (Table 5), nine[5,7,14,15,47,72-75] failed to find an association between the early use of fluoride toothpaste and prevalence of fluorosis. Most of these studies were designed to find the prevalence or trends in fluorosis in the population of interest,[7,73,75] or to find risk factors for fluorosis in populations that had been exposed to multiple sources of systemic fluoride during the period of tooth development.[5,14,15,47,74] The study designs and methodologies were generally well suited to the individual research question, but were not designed to find an association between early use of fluoride toothpaste and prevalence of fluorosis. For example, Driscoll et al.,[75] studying the prevalence of fluorosis in 11 Illinois cities with varying concentrations of fluoride in the drinking water supply, found eight children in the optimally fluoridated areas who had moderate or severe fluorosis. They then interviewed the parents of the eight children by telephone to find the cause of the fluorosis. To find out if fluoride toothpaste was the cause, they asked the parents if the child had ingested "unusual " amounts of fluoride.[75] Another example is the study by Butler et al.[73] In their study of 16 Texas communities with varying concentrations of fluoride in the water used Dean's Index, but dichotomized it into two categories. Moderate and severe fluorosis were in one category, and normal, questionable, very mild, and mild fluorosis were in the other category. Defining fluorosis in this manner would reduce the number of disease cases, because children who had very mild and mild fluorosis were categorized as non-diseased. This categorization would tend to show no association between disease and exposure due to misclassification bias. Further, the ages of the study populations in some of the studies were not appropriate to study the research question.[5,74] Both studies[5,74] used children between the ages of 6-13 years. In the Szpunar and Burt study, 46% of the children were below the age of 7-years. Six-year-old children do not have many erupted permanent teeth, which could have underestimated the prevalence of fluorosis. It is therefore hardly surprising that only one study[6] did find a statistically significant association with an odds ratio of 11 for fluorosis when toothbrushing with a fluoride dentifrice began before the age of two years.

Table 6 reports the results of more recent studies on the association between use of fluoridated toothpaste before the age of six years and dental fluorosis.[6,43,44,46,77-80] The methodologies used in these studies were more suited to test the underlying hypothesis on the association between the use of fluoridated toothpaste and fluorosis. The fluoride toothpaste variables that have been associated with fluorosis are: beginning toothbrushing at a relatively early age;[6,43-45] amount of toothpaste used measured as either toothbrushing frequency,[77,79] amount swallowed,[45,46,80] or the amount of paste used at each brushing.[78] Although the association between toothpaste use and fluorosis was not always statistically significant,[45,47,78] these studies taken together are compelling evidence that use of a fluoride toothpaste before age six is a risk indicator for dental fluorosis.

Table 5. Results of Studies Seeking an Association Between Use of Fluoride Dentifrices and the Prevalence of Fluorosis

Study (Ref)	*Water Fluoride Status*	*Country*	*Fluorosis*	*Finding Index*
Soparkar & DePaola, 1985[72]	Deficient	US	Dean's	No association
Woolfolk et al., 1989[14]	Deficient	US	TSIF	No association
Pendrys & Katz, 1989[15]	Deficient	US	FRI	No association
Holm & Anderson, 1982[47]	Deficient	Sweden	T & F	No association
Kumar et al., 1989[7]	Deficient Optimal Above optimal	US	Dean's	No association
Butler et al., 1985[73]	Deficient Optimal Above optimal	US	Dean's	No association
Szpunar & Burt, 1988[5]	Deficient Optimal Above optimal	US	TSIF	No association
Osuji et al., 1988[6]	Near optimal	Canada	T & F	Positive association
Bohaty et al., 1989[74]	Optimal	US	Dean's	No association
Driscoll et al., 1983[75]	Optimal Above optimal	US	Dean's	No association

Source: Ripa 1991,[71] Journal of Public Health Dentistry

Table 6. Risk of Dental Fluorosis from Use of Fluoride Toothpaste or Variables Associated with Toothpaste Use.

Study	*Country*	*Sample Size*	*Odds Ratio*	*95% CL or P-value*
Early Use of Fluoridated toothpaste:				
Before age two:				
Osuji et al, 1988[6]	Canada	147	11.0	(4.83-25.22)
Pendrys and Katz, 1989[15]	US	850	2.9	(0.5-15.8)•
Milsom and Mitropoulos, 1990[44]	England	321	1.34	*P*<0.05
Lalumandier and Rozier, 1995[40]	US	708	3.0	*P*=0.025
Skotowski et al., 1995[57]	US	157	1.43	(1.01-2.04)
Pendrys and Katz, 1996[41]	US	460	4.23	(1.72-10.41)
Pendrys and Katz, 1998[42]	US	233	8.37	(1.68-41.72)
Mascarenhas and Burt, 1998[76]	India	1,189	1.83	(1.05-3.15)
Kumar and Swango, 1999[58]	US	2,193	2.00	(1.20-3.30)
Other ages:				
Riordan and Banks, 1991[45]				
(<1 yr)	Australia	659	1.35	(0.72-2.55)
(1-3 yr)			1.20	(0.63-2.29)
Holt et al, 1994[65] (2-5 yr)	UK	1,523	1.66	(1.04-2.62)
Wang et al, 1997[66] (< 14 mths)	Sweden	383	2.44	(1.07-5.55)
Swallowed toothpaste:				
Riordan, 1993[46]	Australia	350	1.73	(1.10-2.72)
Liked toothpaste:				
Riordan, 1993[46]	Australia	350	2.61	(1.36-5.01)
Brushing Frequency (more than once a day):				
Pendrys et al, 1993[77]	US	906	3.6	*P*<0.05
Amount of toothpaste used(3/4 of brush head):				
Evans, 1991[78]	England	418	2.0	*P*<0.05

• 99% CL

From Table 6 it is apparent that of the toothpaste use variables, the best indicator of fluorosis was use of fluoride toothpaste before age two years. The risk of developing fluorosis from use of fluoride toothpaste ranged from a slightly increased risk to a child having an 11 times higher risk. The reasons for this wide range are the multiple sources of fluoride and the different indices used to measure fluorosis in each study. Even so, the one study in which fluoride toothpaste was the only potential source of fluoride still showed an association between early fluoride toothpaste use and fluorosis.[76] Further, a study by Holt et al.[65] that evaluated the risk of fluorosis in children who had previously participated in a clinical trial of the caries preventive effects of a low fluoride toothpaste (550 ppm) between the ages of 2 and 5 years[81] showed that children who had used the low fluoride toothpaste were significantly less likely to have fluorosis. Based on the number of well-conducted case control studies, and the strength of the associations seen in the various studies, the risk of fluorosis from early use of fluoride toothpaste is no longer a controversial issue.

To reduce the risk of developing fluorosis, if available, low fluoride or no fluoride toothpaste should be recommended for use in very small or preschool children, or fluoride toothpaste (1000 ppm or higher) should be used under parental supervision. Parents should dispense toothpaste, dispensing only a pea size amount, and supervise toothbrushing to ensure that children expectorate and rinse during toothbrushing.[82]

Other factors

Other factors or sources of fluoride that have been associated as risk determinants, indicators, or factors for fluorosis are reported in Table 7. Variables that have been associated with an increased risk of fluorosis are: socio-demographic variables such as the child's age, gender, and race; parent's income and education levels; feeding practices such as weaning before 9 months of age and breast feeding; and fluoride mouthrinse. Children who were male, Caucasian, and whose parents had higher income and educational levels were more likely to have fluorosis.

Children weaned before 9 months of age or breast fed had a higher risk for fluorosis. Both these indicators are probably surrogates for other variables, therefore not directly causing fluorosis. For example, it is possible that children who were weaned early were then fed infant formulas that were known to have higher fluoride content and so developed fluorosis. Breast milk, on the other hand, is known to contain little fluoride.

Except for one study,[5] at the present time there is little evidence that fluoride rinses, or professional or office based fluoride causes fluorosis. There could be three reasons for this finding. First, these office based procedures are not used very often in very young children; second, if used, smaller amounts of the products are being used than previously because of the introduction of foam products and varnishes rather then gels or solutions; and third, care is taken to reduce the amount

Table 7. Other Factors Associated with Dental Fluorosis

Study	*Country*	*Sample Size*	*Odds Ratio*	*95% CL or P-value*
Age of the Child:				
Szpunar and Burt, 1988[5]	US	556	1.25	(1.13-1.38)
Ismail et al, 1990[8]	Canada	936	1.90	(1.20-3.01)
Gender (male):				
Ismail et al, 1990[8]	Canada	936	1.34	(1.11-1.63)
Race (African American):				
Pendrys and Katz, 1996[41]	US	460	4.28	(1.34-13.72)
Kumar and Swango, 1999[58]	US	2,193	2.3	(1.80-3.00)
Parent's Income Level (higher):				
Bagramian et al, 1989[64]	US	206	0.91	(0.31-2.76)
Pendrys and Katz, 1996[41]	US	850	6.6	(1.1-39.5)*
Parent's Education Level (higher):				
Bagramian et al, 1989[64]	US	206	2.7	(1.29-5.73)
Clark et al., 1994[59]	Canada	1,131	1.2	$P<0.02$
Weaning Before 9 Months of Age:				
Riordan 1993[46]	Australia	350	1.81	(1.09-3.01)
Breast Fed:				
Pendrys and Katz, 1996[41]	US	460	1.62	(1.03-2.55)
Kumar et al., 1998[83]	US	1,493	1.40	(1.00-1.88)
Fluoride Rinse:				
Szpunar and Burt, 1988[5]	US	556	1.57	(1.02-2.41)

* 99% CL

swallowed by using custom trays with liners. Fluoride rinses should not be prescribed to children below the age of six years, and care needs to be taken when using professional or office based fluoride products in this age group as they could swallow a substantial amount of these products, causing fluorosis to develop.

Conclusion

In summary, there is substantial evidence that fluoridated water, fluoride supplements, infant formulas, and fluoride toothpastes are risk factors for fluorosis, with increasing risk from the use of any one product as the number of products used by the individual increases.[40,43,76] Care should be taken when recommending the use of these products in children below the age of six years. Further, the profession needs to make conscious efforts through education to increase the awareness of it members, and of the medical professionals who prescribe the use of these products to patients. The profession also needs to educate their patients and the public on the appropriate use of these products, while not causing public alarm. The following are some recommendations that would reduce the risk of fluorosis:

1. Before fluoride supplements are prescribed clinicians should consider the fluoride content of the water consumed and the caries risk of the child, and be aware of the appropriate dosage for fluoride supplementation.
2. Fluoride rinses should not be prescribed to children below the age of six years.
3. Parents should be encouraged to use ready-to-feed formulas, or use non-fluoride containing bottled water to dilute formula concentrate.
4. Low fluoride or no fluoride toothpaste if available should be recommended for use in very small or pre-school children if available, or fluoride toothpaste (1000 ppm or higher) should be used under parental supervision.
5. Only parents should dispense toothpaste, dispensing only a pea size amount.
6. Parents should supervise toothbrushing to ensure that children expectorate and rinse during toothbrushing.

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