

Ingestion of Fluoride from Dentifrices by Young Children and Fluorosis of the Teeth – A Literature Review

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*The ADA recommends the use of fluoridated dentifrices as soon as the primary teeth erupt, so as to reduce the incidence of dental caries. However, young children can ingest a significant amount of dentifrice during normal toothbrushing; this is a potential problem because the permanent teeth are at risk from fluorosis for the first seven years of life. **Aims:** the objective of this paper was to review the literature on the role of fluoride dentifrices in causing dental fluorosis. **Methods:** Search strategy: a search for literature was performed using MEDLINE, OVID with the key words fluorosis, dentifrice, ingestion, and children. The search was limited to English language publications. Subsequently, 31 articles were retrieved, additional relevant articles were collected from the references cited in the initially identified papers. Ultimately, 96 articles were retrieved for review. **Conclusions:** Fluoride, should be used with caution so that the benefits out-way the adverse affects. Oral health care providers need to systematically assess individual tooth brushing habits and emphasize the advantages of early use of a fluoridated dentifrice whilst still meeting the need for the prudent use of small quantities of dentifrice.*

Dentifrices with a low concentration of fluoride may be appropriate for young children who are considered to be at low caries risk and the risk of fluorosis is minimal for children who ingest this dentifrice; nevertheless, it appears that more research is still required on the therapeutic effects of fluoride dentifrices which contain fluoride at a low concentration.

Keywords: fluorosis, children, dentifrice, ingestion.

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INTRODUCTION

The value of fluoridated oral health products, as a means of preventing dental caries, has led to the development of different delivery modes such as adding it to public water supplies, dietary supplements such as drops and tablets, topical agents for professional use, dentifrices and mouthwashes.^{1,2} Dentifrices are the most widely used source of topical fluoride for children. Other important sources of fluoride for young children are water, formula

milk, other infant foods, juices, and a range of products for professional topical application.³

Currently, the cariostatic effect of fluoride is considered to be due primarily to its presence in the oral cavity post-eruptively where it is able to enhance remineralization of early carious lesions and to decrease the rate of enamel demineralization.⁴⁻⁶

Early carious lesions can be remineralized, under both *in vitro*^{7,8} and *in vivo*^{9,10} conditions and the role of fluoride in remineralization has been well researched.¹¹⁻¹³ From the literature it appears that fluoride is able to increase the rate of repair of carious enamel lesions by enhancing remineralisation,^{7,14-16} and increasing the resistance of remineralized areas to secondary acid attack.^{17,18}

In addition to the beneficial effects of fluoride the adverse action of excessive amounts can cause fluorosis following intentional and unintentional ingestion of topical fluoride products such as dentifrice. Therefore, the objective of this review was to study the published literature on the potential role of fluoridated dentifrices in causing dental fluorosis.

Search strategy: A search for literature was performed using MEDLINE, OVID. The key words used were fluorosis, dentifrice, ingestion, and children. The search was limited to studies on humans which were published in English. 31 articles were initially retrieved; additional relevant articles were collected from the references cited in the initial

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papers. Ultimately, 96 articles were retrieved and critically appraised.

Anti-caries effects of fluoridated dentifrices

The first report of the ability of a fluoride containing dentifrice to reduce the incidence of caries in children was published in 1954.¹⁹ Since that time fluoride dentifrices have become popular and widely used products that have been acknowledged as the main reason for the recent decline in dental caries²⁰ in many developed countries since the 1970s.²¹

Holt and Murray,²² in their review identified 100 clinical trials which showed that brushing with a fluoridated dentifrice significantly reduced the incidence of dental caries.

The anticaries effect of fluoridated dentifrice is due to the topical effect of fluoride on the dental enamel. The fluoride from the dentifrice reacts with the hydroxyapatite crystals of the enamel and forms fluorapatite. Fluorapatite is more stable to acid challenge and hence resistant to caries. Restorative materials like GIC (used in caries stabilization) act as a reservoir of fluoride, which gets slowly released over an extended period of time.

The anti-caries action of fluoridated dentifrice is affected by the frequency of use.^{23,24} In a 3 year clinical trial, once a day brushers had 20-30% higher caries increments than twice a day brushers.²⁵

White,²⁶ from his study on the reactivity of fluoridated dentifrices on artificial carious lesions drew a number of

conclusions; (i) sodium fluoride and amine fluoride containing dentifrices demonstrated similar reactivity in promoting remineralisation, surface hardening and fluoride uptake into early carious lesions; both agents resulted in substantial increases in fluoride uptake which was presumed to be responsible for the increase in remineralization that was observed, (ii) monofluorophosphate (MFP) was less reactive, in all aspects, relative to the sodium fluoride and amine fluoride preparations, and (iii) that although MFP treated specimens exhibited significantly increased surface hardening, relative to the placebo, radiographically they did not exhibit significantly enhanced remineralization. Other workers^{27,28} have also shown that not all forms of fluoride are equally effective. For example, MFP diffuses more slowly into enamel²⁷ and is more easily removed by water and acidic rinses²⁸ than ionic fluoride.

Bioavailability of fluoride from fluoridated dentifrices depends on the type of abrasive present. If a fluoride dentifrice is to be effective, its fluoride must be present in a chemically reactive (ionic) and stable form. It is likely that early clinical tests of fluoride dentifrices produced negative results because the abrasive salt (calcium carbonate or calcium phosphate) and the fluoride agent used (sodium fluoride) were incompatible. To achieve the anti-caries activity of fluoridated dentifrice, the fluoride present in the dentifrice should be soluble and it is important that the abrasive used does not make it insoluble.^{29,30}

Table 1. Findings from the studies showing the anti-caries effect of fluoridated dentifrices.

Author	Year	Type of study	Sample	Findings
Muhler <i>et al</i> ¹⁹	1954	Non-randomized controlled	514 (6 to 15 yrs)	53% reduction in DMFT and 72% reduction in DMFS by dentifrice containing 1000 ppm stannous fluoride.
Gron <i>et al</i> ²⁸	1971	<i>In vitro</i> and <i>in vivo</i>	2 subjects (study on intraoral stability of MFP)	Minimum fluoride was deposited from MFP in intact enamel. Retained MFP from the use of a rinse hydrolyzed rapidly in the mouth.
De Rooij <i>et al</i> ²⁷	1981	<i>In vitro</i> with bovine enamel	Not specified	Diffusion co-efficient for the fast diffusion of MFP ion was 3 times smaller than the diffusion coefficient for the fast diffusion of fluoride ion.
White ²⁶	1987	<i>In vitro</i>	24 enamel samples- 6 groups of 4 specimens	The dentifrices with sodium and amine fluoride were found to be extremely effective in enhancing the remineralization and acid resistance of early carious lesions.
Chesters <i>et al</i> ²⁴	1992	Clinical trial	3,005 (mean age 12.5 yrs)	Caries increment was less in those who brushed their teeth twice a day.
O'Mullane <i>et al</i> ²³	1997	Randomized controlled trial	4196 (11 to 12 yrs)	Three year DMFS scores were lower for those who brushed more frequently and who did not rinse after toothbrushing.
Chestnutt <i>et al</i> ²⁵	1998	Clinical trial	2621 (mean age 12.5 yrs)	Mean DMFS scores (for 3 years) in those who brushed <1/day, 1/day or >1/day were 8.90, 6.63 and 5.48 (P<0.01) respectively.

Table 2. Summary from the studies showing the anti-caries effect of fluoridated dentifrices.

- Dentifrice containing 1000 ppm stannous fluoride results in pronounced reduction of dental caries.
- MFP diffuses more slowly into enamel than ionic fluoride.
- MFP is more easily removed by water and acidic rinses than ionic fluoride.
- Sodium fluoride and amine fluoride have high reactivity and MFP has low reactivity.
- The anti-caries effect of fluoridated dentifrice is affected by the frequency of use.

Age of commencement and the use of fluoridated dentifrices by children

Palmer and Prothero³¹ reported that 72% of British children aged 17 months and 98% aged 36 months used a fluoridated dentifrice with the majority starting before 12 months of age. Other workers³² have reported that the percentage of infants whose teeth were brushed with a fluoridated dentifrice increased substantially between the ages of 6 and 12 months; such that the large majority used a fluoridated dentifrice before the age of one year. However, concerns were expressed that some young children could be exposed to fluoride in large enough quantities to have a systemic effect during the formative period of not only their permanent teeth, but also some of their posterior primary teeth.³³ Consequently, it has been suggested that, parents

should be advised to delay the use of a fluoridated dentifrice until the child is 24 months of age.³⁴ This is in contrast to the recommendation of the American Dental Association in “A guide to the use of fluorides” which recommends use of a fluoridated dentifrice when the first primary tooth erupts.³⁵

This seems, at least superficially, to ignore the findings of a number of studies which have identified early or excessive use of fluoridated dentifrices as being important risk factors for dental fluorosis.³⁶⁻³⁹ Interestingly, Naccache⁴⁰ found that 77% of children aged between 2 and 7 years placed dentifrice on their own toothbrushes. As this is a likely source of excessive use of dentifrice, parents should supervise their child’s toothbrushing.

There are differences in the recommendations made by different international organizations regarding the appropriate age for the beginning of fluoride dentifrice use. The Centre for Disease Control and Prevention (CDC), USA⁴¹ recommends that children less than 2 years should not use fluoridated dentifrices. Australian Research Centre for Population Oral Health (ARCPOH)⁴² recommends that children less than 18 months should not use fluoridated dentifrices. European Association of Pediatric Dentistry (EAPD)⁴³ and Scottish Intercollegiate Guidelines Network (SIGN)⁴⁴ recommend using fluoridated dentifrice soon after the eruption of the primary teeth. World Health Organization (WHO)⁴⁵ and British Society of Paediatric Dentistry (BSPD)⁴⁶ had not given any specifications regarding the use of fluoridated dentifrice for children less than 2 years of age.

Table 3. Findings from the studies showing the age of commencement and the use of fluoridated dentifrices by children.

Author	Year	Type of study	Sample	Findings
Palmer and Prothero ³¹	1981	Questionnaire-reported by parents	411 and 487 parents of 17 mos and 3 yr old children respectively	The parents of 23% of the 3 yr old children reported that most of the dentifrice was ingested during toothbrushing episodes.
Milsom and Mitropoulos ³⁷	1990	Prevalence	91 children from the fluoridated region and 131 children from non-fluoridated region	Enamel defects in children from fluoridated region were found significantly higher in those who started toothbrushing at an early age.
Simard <i>et al</i> ³⁴	1991	Cross sectional	36 children (12 to 24 months old)	20% of the children ingested >0.25 mg of fluoride per day by toothbrushing alone.
Naccache <i>et al</i> ⁴⁰	1992	Interventional	405 (2 to 7 yrs)	The amount of dentifrice used accounted for 60% of the total variation of 66% in the amount of fluoride ingested.
Lalumandier and Rozier ³⁹	1995	Case control	708 (5 to 19 yrs)	For subjects drinking fluoridated water, fluorosis was associated with age of child when brushing was initiated (OR = 3.1).
Skotowski <i>et al</i> ³⁸	1995	Case control	157 children (8 to 17 yrs)	The risk of fluorosis was significantly higher for children with greater exposure to fluoridated water and who used larger amounts of fluoridated dentifrice up to age 8.
Levy <i>et al</i> ³²	1997	Prospective (Questionnaire about infants at ages 6 weeks and 3,6,9,12 months of age)	1374 mothers	Mean quantities of fluoride dentifrice used were 0.21, 0.20, and 0.19 mg F per day (range up to 1.75 mg).

The reason for the contrast in the recommendations globally could be due to the ethnic differences in the development of the swallowing reflex in children.

Table 4. Summary from the studies showing the age of commencement and the use of fluoridated dentifrices by children.

- 72% of 17 months old and 98% of 36 months old British children started using fluoridated dentifrice before one year of age.
- In fluoridated communities, significantly more children who began brushing at an early age exhibited enamel defects.
- The amount of fluoride ingested from dentifrice could constitute a substantial proportion of the total daily intake of fluoride among 12 to 24 months old children.
- The quantity of dentifrice used was the most important factor affecting the ingestion of fluoride from toothbrushing by young children.
- For subjects drinking fluoridated water, fluorosis was associated with age of child when brushing was initiated.
- The risk of fluorosis was significantly greater for children who had greater exposure to fluoridated water and who used larger amounts of fluoridated dentifrice up to age eight.
- Fluoride dentifrice usage among infants varies greatly and can be a risk factor for dental fluorosis.

Age as a risk factor for developing fluorosis

Fluoride affects the activity of ameloblasts⁴⁷ especially during the late secretory, and early maturation phases of amelogenesis.⁴⁸ Although there are data that demonstrate the importance of the post-secretory and maturation phases of amelogenesis, the most critical period of greatest fluorosis

risk for the maxillary central incisors is from 20 to 28 months.⁴⁷⁻⁵³ Nevertheless, some authors have identified an “epidemiological window” between 4 and 24 months during which the maxillary central incisors are most susceptible to dental fluorosis.⁵¹

Furthermore, the most critical period for fluorosis in the permanent dentition is considered to be during the latter stages of pre-eruptive tooth development; for the anterior permanent teeth which is between 22 and 25 months of age.⁵⁴ Teeth in the permanent dentition are at risk of fluorosis during the first 7 years of life; hence excessive fluoride ingestion by a child over 7 years of age will not cause dental fluorosis.⁵⁵

Study on prenatal fluoride supplementation shows there were no statistically significant differences between the test group (in which 1 mg fluoride containing tablet was given during the last 6 months of pregnancy) and the control with respect to fluorosis in primary teeth.⁵⁶

Table 6. Summary from the studies showing the age as a risk factor for developing fluorosis.

- The developing permanent maxillary central incisors are most susceptible to dental fluorosis between 4 and 24 months of age.
- Excessive fluoride ingestion by a child over 7 years of age will not cause dental fluorosis.
- The most critical period for fluorosis of the anterior permanent teeth is between 22 and 25 months of age.
- Prenatal fluoride supplements have not been found to be a significant cause of fluorosis of the primary teeth.

Table 5. Findings from the studies showing the age as a risk factor for developing fluorosis.

Author	Year	Type of study	Sample	Findings
Larsen <i>et al</i> ⁴⁸	1985	Cross sectional	110 (6 yrs 5 mos to 13 yrs 2 mos)	Fluorosis was observed on the maxillary central incisors in 90% of the children who received fluorides between 2.5-3.4 yrs of age.
Richards <i>et al</i> ⁴⁹	1986	Animal	16 pigs	The test group (received 2 mg F/Kg/day from 8 months of age) developed diffuse enamel hypomineralization indistinguishable from human fluorosis.
Evans ⁵⁰	1989	Retrospective cohort	2382 (7 to 13 yrs)	Dental fluorosis may occur over a period of 16 to 24 mos, starting from 12 to 32 mos following enamel secretion.
Evans and Stamm ⁵¹	1991	Retrospective cohort	1,062 (7 to 12 yrs)	Dental fluorosis prevalence decreased from 64 to 47 % after downward adjustment of drinking water fluoride.
Ishii and Suckling ⁵⁵	1991	Prospective cohort	86 (7 yrs at outset or 11 mos or more at removal of the high-F water)	Risk periods for the production of moderate or severe fluorosis were (i) from birth until early stage of tooth development (ii) from later stage of development until eruption.
Leverett <i>et al</i> ⁵⁶	1997	Randomized clinical trial	1,400 pregnant women (fluorosis was assessed at age 5 yrs in 798 children)	No statistically significant differences in the study groups (Prenatal fluoride supplement group vs control) with respect to caries and fluorosis in primary teeth.
Van Palenstein Helderman <i>et al</i> ⁵³	1997	Prevalence	1566 (12 to 17 yrs)	The later in life that enamel is completed, the higher the severity of dental fluorosis.

Optimum level of fluoride intake by children

The objective of any fluoridated preventive therapy is to attain the maximum anti-caries benefit with the minimum risk of fluorosis. The uppermost limit of fluoridated intake has been estimated to be 0.05-0.09 mg/kg body weight *per day*,^{57,58} from all dietary and non-dietary sources. However, this figure is only an estimate and the “optimal” level of intake may be as low as 0.03-0.04 mg/kg body weight *per day*.⁵⁹

The mentioned dose in practical term could be easily reached by the use of fluoridated dentifrice. Hence it is very important to keep the level of fluoride intake by a child as low as possible. A most important measure would be to try and reduce the ingestion of fluoride from fluoridated dentifrice by children. Tube orifice of a fluoridated dentifrice could be designed to be small so that it could not dispense dentifrice in excess, but it is uncertain to tell whether this would still be a successful measure. Alternatively the head of a toothbrush could be designed to be small in size so that the child would not dispense dentifrice in excess.

It is important to know the role of gastric content in the absorption of ingested fluoride. The ingested fluoride does not get absorbed to the same extent every time as the food present in the stomach delays absorption of the ingested fluoride.⁶⁰

Table 8. Summary from the studies showing the optimum level of fluoride intake by children.

- Optimum level of fluoride intake for children is 0.03-0.04 mg/kg body weight *per day*.
- The uppermost limit of fluoride intake (from all dietary and non-dietary sources) has been estimated to be 0.05-0.09 mg/kg body weight *per day*.
- Food present in the stomach delays absorption of the ingested fluoride.

Ingestion of fluoride from dentifrices and fluorosis of teeth in young children

Although the intake of fluoride from drinking water is the major cause of dental fluorosis; ingestion of fluoridated dentifrices by pre-school children contributes to the problem.⁶¹⁻⁶³ By considering the number of daily brushing exercises and the optimum quantity of fluoride recommended for children, based on age, it has been determined that from toothbrushing alone, approximately 33% of children receive an amount of fluoride that was in excess of the recommended dose.⁶⁴ The amount of dentifrice ingested has been found to positively correlate with the amount used^{65,66} and is directly associated with the children's age.⁶⁷⁻⁶⁹ Several factors may influence the amount of dentifrice used and thus the amount retained; these include the length of the head of the toothbrush, the diameter of the orifice of the dentifrice tube,⁶⁵ the flavor of the dentifrice,⁶⁷ and most importantly, the ability of the child to avoid ingestion by being able to successfully expectorate the residual dentifrice after toothbrushing. Despite placing similar amounts of dentifrice on toothbrushes, younger children ingest greater amounts of fluoride when toothbrushing than older children, probably due to inadequate control over their swallowing reflexes.⁷⁰ Young children can ingest enough fluoride, from dentifrices alone, to pose a significant risk of developing dental fluorosis.⁷¹ Ericsson and Forsman⁷² supervised the toothbrushing of 72 months old children, and performed toothbrushing for a group of 48 months old children. The younger children used 0.45 g of dentifrice and retained 0.13 g (range 0.04 to 0.30 g) meaning that 30% was ingested. The 72 months old children, who also used 0.45 g of dentifrice retained 0.12g (range 0.06 to 0.19 g) resulting in 26% being ingested. Very little data are available for children in the 24 months and younger age range; though it can be assumed that greater amounts will be ingested. Regardless, of the accuracy of these figures and those from other studies, it is apparent that

Table 7. Findings from the studies showing the optimum level of fluoride intake by children.

Author	Year	Type of study	Sample	Findings
Fejerskov ⁵⁹	1987	<i>In vitro</i>	46 primary teeth from children exposed to fluoride and 22 teeth from children exposed to minimal or no fluoride	In the fluoride group (>1000 ppm), the fluoride distribution pattern was higher in the outer enamel compared to the control group (<200 ppm).
Burt ⁵⁷	1992	Review	Review of evidence for an increase in fluoride ingestion from all sources since 1970	Ingestion of fluoride from diet (0.2-0.3 mg per day) and from fluoride dentifrice (0.2-0.3 mg per day) can lead the children to reach the upper limit of fluoride intake.
Cury <i>et al</i> ⁶⁰	2005	Controlled clinical trial	11 children (17 to 20 yrs)	Only 10% higher F absorption with ingestion of conventional dentifrice after lunch compared to a low-F dentifrice ingested when fasting.
Miziara <i>et al</i> ⁵⁸	2009	Cross sectional	Parents of 379 children residing in optimally fluoridated area	Dentifrices and diet contributed to 56.3% and 43.7% of the daily fluoride intake, respectively.

young children can inadvertently swallow a significant amount of dentifrice during toothbrushing.^{73,74} Even more worrying is that some children under 12 months of age consume dentifrice directly from the tube.^{32,75} Thus, it is clear that the younger the child, the larger the proportion of dentifrice ingested.⁶⁹ Children who do not rinse their mouths after toothbrushing ingest approximately 75% more dentifrice than those who rinse after toothbrushing (0.45 g vs. 0.25 g).⁶⁹ It has been estimated that approximately 0.5 mg of fluoride may be ingested by children when a 1,000 ppm F dentifrice is used twice daily; this demonstrates the potential of fluoridated dentifrices to be a significant source of fluoride intake.⁷⁶ Amongst 4 and 5 year old children rinsing has been shown to be associated with significantly less ingestion of dentifrice, 0.17 mg vs. 0.25 mg of fluoride respectively. Older children learn to expectorate properly and so ingest less dentifrice whether rinsing or not.³⁹ In one study of dentifrice usage amongst children below the age of 4 years it was found that the majority of those who rinsed with water, ingested all or most of the rinse instead of expectorating it.⁷⁷ Younger children tend to rinse and expectorate less frequently and, therefore, ingest a larger proportion of the dentifrice.⁵¹ In the study by Bentley and co-workers,⁷⁸ 72% of the dentifrice applied to the toothbrush was retained in the mouth and therefore presumed to have been ingested. Interestingly, children from high socioeconomic groups place approximately 24% more dentifrice on their toothbrush than their counterparts from lower socioeconomic classes.⁷⁹

One factor that may contribute to the amount of dentifrice ingested could be the quantity of detergent present in the formulation. This is because dentifrices with a low detergent content generate less foam during brushing and are said to therefore offer a smaller risk of ingestion.⁷⁹

Surprisingly, it has been stated that healthcare professionals have made little effort to explain to their parents

and/or caregivers the risks and benefits of fluoridated dentifrice usage by children.⁸⁰

Table 10. Summary from the studies showing the ingestion of fluoride from dentifrices and fluorosis of teeth in young children.

- Young children can inadvertently swallow a significant amount of dentifrice during toothbrushing.
- The amount of dentifrice ingested correlates positively with the amount used.
- The amount of dentifrice ingested is directly associated with the children's age.
- Some children under 12 months of age consume dentifrices directly from the tube.
- Although the intake of fluoride from drinking water is the major cause of dental fluorosis, ingestion of fluoridated dentifrices by pre-school children contributes to the problem.
- The majority of children below 4 years old who rinsed with water ingested all or most of the rinse instead of expectorating it.
- 72% of the dentifrice applied to the toothbrush was retained in the mouth and therefore presumed to be ingested.
- Children from high socioeconomic groups place approximately 24% more dentifrice on their toothbrush than their counterparts from lower socioeconomic classes.

Fluoridated dentifrices flavored for children

Fluoridated dentifrices for children are flavored in various forms and as such flavours are usually used in confectionaries and sweets, children tend to dispense increased quantity of dentifrices, brush for a longer time period and expectorate less. This leads to increased risk of fluoride ingestion and subsequent development of fluorosis.^{81,82,83} The amount of dentifrice that is used and ingested is probably correlated with the pleasantness of the flavour.

In the study by Oliveira *et al*⁸³ fluoride intake was slightly higher with the use of dentifrices flavored for children whilst

Table 9. Findings from the studies showing the ingestion of fluoride from dentifrices and fluorosis of the teeth of young children.

Author	Year	Type of study	Sample	Findings
Pendrys and Katz ⁶²	1989	Case control	850 (11 to 14 yrs)	Mild-to-moderate enamel fluorosis strongly associated with fluoride supplementation during the first 6 years of life (OR = 4) and with median household income (OR= 6.6).
Woltgens <i>et al</i> ⁶³	1989	Cross sectional	83 (mean age 13.5 yrs)	The number of teeth affected and the degree of mottling was higher in children who used F at early age.
Levy <i>et al</i> ⁷⁷	1993	Cross sectional	59 (1 to 4 yrs)	Children who did not rinse or expectorate after tooth brushing were 49%. Those who rinsed but ingested all or almost all of the rinse were 27%.
Bentley <i>et al</i> ⁷⁸	1999	Cross sectional	50 (30 mos)	Average of 0.42 mg of F was ingested after toothbrushing with 1,450 ppm F dentifrice and 0.10 mg when using the 400 ppm F dentifrice.
Puppin Rontani <i>et al</i> ⁷⁹	2002	Cross over	124 (3 to 9 yrs) from different socioeconomic groups	The quantity of the dentifrice on toothbrush, amount ingested and brushing time were influenced significantly by the dentifrice brand.

Moraes *et al*⁶⁶ in their study found that dentifrice flavor did not influence the percentage of fluoride intake.

Therefore, parents should be warned that a flavored dentifrice, may lead to excessive ingestion of the dentifrice by some children. The direct ingestion from the dentifrice tube, known as “intentional ingestion,”³² may occur as a result of children experimenting with the pleasant flavour, or the attractive color, or the presence of colored strips or other visual characteristics.

Table 12. Summary from the studies about the fluoridated dentifrices flavored for children.

- Preschool children use large amounts of dentifrice, brush for longer periods of time, rinse and expectorate less when using a flavored dentifrice.
- The amount of dentifrice that is used and ingested is probably correlated with the pleasantness of the flavor.

Measures to reduce the ingestion of fluoridated dentifrices

Fluoride, from whatever source should be used cautiously so that the caries preventive benefits are maximized and the adverse effects of inappropriate use are reduced.^{84,85} It will always be necessary for providers to systemically assess individual toothbrushing habits on a regular basis in order to both emphasize the advantages of early use of a fluoride containing dentifrice and the need for the prudent use of small quantities under proper supervision.³² One way of reducing the amount of fluoride ingested is to minimize the amount that is dispensed for use. Another approach is to reduce the concentration of fluoride in a dentifrice to either 500 or 250 ppm fluoride.⁸⁶

The use of dentifrices with high concentrations of fluoride by preschool children, should be avoided^{53,57,69,81} except when clinically indicated by high caries levels, or the existence of a significant medical condition. Nevertheless, while

small quantities of fluoridated dentifrices may carry a lower risk of fluorosis, this must be balanced against the associated reduction in the therapeutic cariostatic effects.²²

Table 13. Summary from the studies about the measures to reduce the ingestion of fluoridated dentifrices.

Fluoride ingestion from dentifrices could be reduced by either reducing the amount of toothpaste dispensed on the toothbrush or by reducing the concentration to 500/250 ppm of fluoride.

Dentifrices with a low fluoride concentration

The results of the study by Holt and her co-workers⁸⁷ indicated that the use of a dentifrice with low fluoride content, by pre-school children, living in districts with less than 0.58 ppm fluoride in the public water supply, during the period of incisor tooth mineralization, brought about only a small reduction in the prevalence of enamel opacities (fluorosis). Therefore, in order to minimize the risk of dental fluorosis, from inadvertent ingestion, by young children, low fluoride concentration dentifrices were marketed. Dentifrices containing 500-600 ppm fluoride are considered to be appropriate for use by young children,⁸⁸ and high fluoride content dentifrices should not be used by children below 6 years of age. Recently, many questions have been raised about the relative efficacy of dentifrices with different fluoride contents. In a concentration below 1000 ppm, the question is, do these dentifrices achieve an optimal anticaries effect while reducing the risk of fluorosis?⁸⁶ In principle, low fluoride concentration dentifrices provide less protection against dental caries, but reduce the risk of fluorosis. They may therefore be appropriate for young children who are considered to be at low caries risk.⁸⁹ The amount of dentifrice used radically affects the total amount of fluoride that can be ingested. For example, a strip of dentifrice containing 1000 ppm F and covering the toothbrush head contains fifteen times more fluoride than a blob of dentifrice which covers

Table 11. Findings from the studies about fluoridated dentifrices flavored for children.

Author	Year	Type of study	Sample	Findings
Levy <i>et al</i> ⁸²	1992	Comparative study with the cross over design	29 (1 to 4 yrs)	Average of 0.153 g more dentifrice flavored for children was used compared to regular flavored dentifrice.
Adair <i>et al</i> ⁸¹	1997	Randomized control trial with cross over design	50 (31 to 60 mos)	A “risk factor” (dentifrice weight x usage time) was derived to estimate the relative fluoride exposure of each child. The mean risk factor for child dentifrice (58.54, 64.8 SD) was significantly greater than that for adult dentifrice (27.43, 25.0 SD, P < 0.001).
Oliveira <i>et al</i> ⁸³	2007	Randomized controlled trial	42 (20 to 30 mos)	Mean fluoride ingestion from regular dentifrices and from those flavored for children was 0.567 +/- 0.300 and 0.630 +/- 0.320 mg F/day, respectively.
Moraes <i>et al</i> ⁶⁶	2007	Randomized controlled trial	33 (24 to 36 mos)	Average 0.022 mg/kg and 0.032 mg/kg of F/day was ingested from unflavored and flavored dentifrices groups respectively.

Table 14. Findings from the studies about the dentifrices with a low fluoride concentration.

Author	Year	Type of study	Sample	Findings
Holt <i>et al</i> ⁸⁷	1994	Controlled clinical trial	1,523 (2 yrs at outset)	The prevalence of enamel opacities was significantly lower in the children who used the dentifrice with lower fluoride content.
Rock and Sabieha ⁸⁸	1997	Comparison of clinical findings with retrospective survey data	325 (8 to 9 yrs)	Significant associations were found between estimated fluoride ingestion from dentifrice and fluorosis.

only one third of the length of the toothbrush head at a concentration of 200 ppm fluoride.⁹⁰ Bentley and co-workers⁶⁴ found that if a 400 ppm fluoride containing dentifrice was used twice daily no child with an average body weight would exceed an ingestion rate of 0.05mg fluoride/kg body weight, whereas children of average weight would exceed this value if they were to use a 1450 ppm F dentifrice. However, it has been ascertained that this fact is unappreciated by most patients.⁶⁹

Table 15. Summary from the studies about the dentifrices with a low fluoride concentration.

Dentifrices containing 500-600 ppm fluoride are considered to be appropriate for use by young children and high fluoride content dentifrices should not be used by children below 6 years of age.

Anti-caries efficacy of low fluoride containing dentifrice

It is possible to improve the efficacy of a dentifrice by reducing the pH. For example, an acidulated 550 ppm fluoride dentifrice has the same anti-cariogenic action as a 1100 mg fluoride preparation that has a neutral pH.⁹¹

There may be differences between primary and permanent teeth in respect of their reactivity to caries challenges⁹²

and thus the effectiveness of low fluoride formulation dentifrices remains unclear.⁹³

In addition, no significant differences have been found in

Table 17. Summary from the studies about the anti-caries efficacy of low fluoride containing dentifrices.

- No significant differences have been found in the prevalence of caries in either the primary or permanent teeth, although there seems to be a trend in both cases for slightly more caries in children who use a 550 ppm F dentifrice.
- An acidulated 550 ppm fluoride dentifrice has the same anti-cariogenic action as an 1100 mg fluoride preparation that has a neutral pH.
- 250 ppm fluoride dentifrice is not as effective in caries prevention in the permanent dentition as a dentifrice containing 1,000 ppm F or more.
- A pea-sized portion (0.32g) of 500 ppm F dentifrice slowed down the demineralization progression better than a half-pea-sized portion.
- A child formula dentifrice containing 500 ppm sodium fluoride showed evidence of remineralization *in vitro*.
- 500 ppm NaF dentifrice demonstrated remineralization of carious lesions *in vitro*; whereas dentifrices that contained AmF, MFP and MFP with xylitol decelerated the progression of demineralization.

Table 16. Findings from the studies about the anti-caries efficacy of low fluoride containing dentifrices.

Author	Year	Type of study	Sample	Findings
Ammari <i>et al</i> ⁸⁶	2003	Systematic review of randomized controlled trials	7 randomized controlled trials	Compared to 1000 ppm F dentifrice, the 250 ppm F dentifrice had 0.6-0.7 higher DFS increments.
Thaveesangpanich <i>et al</i> ⁹⁴	2005	<i>In vitro</i>	150 longitudinal primary teeth sections	Lesions progressed by 64% and 61% respectively in groups treated with half pea sized portions (0.16 g) of 500ppm F dentifrice, while those progressed by only 19% and 23% in groups treated with pea sized portions (0.32 g).
Brighenti <i>et al</i> ⁹¹	2006	<i>In vitro</i>	156 bovine enamel blocks (12 groups of 13).	550 µg F/g acidified paste had same anticariogenic action as 1,100-µg F/g neutral paste.
Itthagaran <i>et al</i> ⁹⁵	2007	<i>In vitro</i>	21 longitudinal primary teeth sections	Reduction of 3% in mean lesion depths of the sections was noticed in the group which used 500 ppm of sodium fluoride.
Ekambaram <i>et al</i> ⁹⁶	2011	<i>In vitro</i>	50 longitudinal primary teeth sections	Significant decrease in lesion depths were found in the sections treated with dentifrice containing 500 ppm NaF.

the prevalence of caries in either the primary or permanent teeth, although there seems to be a trend in both cases for slightly more caries in children who use a 550 ppm F dentifrice.⁸⁷ Investigators should evaluate clinically the efficacy of dentifrices with 500 ppm F so as to determine the real *in vivo* anti-caries effects on primary teeth⁸⁷ because the laboratory findings provided mixed results of mineralization of artificial carious lesions.^{94,95,96}

CONCLUSIONS

Fluoride, from whatever source, should be used with caution so that the benefits match, or even out way the inappropriate affects. It will continue to be essential for oral health care providers to systematically assess individual toothbrushing habits on a regular basis in order to both emphasize the advantages of early use of a fluoridated dentifrice whilst still meeting the need for prudent use of small quantities of dentifrice under proper supervision. One way of reducing the amount of fluoride ingested is to minimize the amount that is dispensed onto the toothbrush. Another approach is to reduce the concentration of fluoride in dentifrices to either 500 ppm, or even down to 250 ppm fluoride. While it has been reported that rinsing the mouth after toothbrushing can lessen the amount of fluoride ingested by older children, younger children tend to swallow the dentifrice whether or not they rinse their mouths with water after toothbrushing. While the use of a high fluoride containing dentifrice may result in a modest increase in efficacy, the potential risk of fluorosis, due to inadvertent ingestion, is significantly greater and does not appear to be justified. Nevertheless, low fluoride dentifrices may well be appropriate for young children who are considered to be at low caries risk. However, at this time there are only minimal good quality research data available on the efficacy of low fluoride containing dentifrices for the remineralization of carious lesions in primary teeth.

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