Fluoride has been the keystone to the prevention of dental caries for over 40 years. It is now made available to many communities through the adjustment of the fluoride concentration in public water supplies, via toothpastes, mouth-rinses, and tablets or drops used as dietary supplements. Individually and collectively these sources of fluoride are considered the main factors responsible for the dramatic decrease in caries activity seen in children and adolescents. However, the increasing number of additional fluoride sources other than water fluoridation is also the most likely cause of most of the observed increase in dental fluorosis in recent times. It is therefore an appropriate time to consider the increased prevalence of dental fluorosis in relation to the high level of caries control afforded by fluoride.

What is fluoride?
Fluoride occurs naturally in rocks, soils and the sea, and is found in ground water supplies. The earth’s crust contains about 900 parts of fluoride per million (ppm), and the content of seawater is about 1ppm. In living tissues, fluoride has always been present in animals (mainly in dental enamel and bone) and in plants. Small amounts are also present in almost all foods. In humans, fluoride is a normal constituent of tooth enamel, incorporated into the crystalline structure of the developing tooth.

Anticaries mechanisms of fluoride
The role of fluoride in the prevention of dental caries has been recognised for over 50 years. Two mechanisms have been proposed to explain the influence of fluoride on caries activity: the predominant ‘post-eruptive’ mechanism and less important ‘pre-eruptive’ mechanism.

Post-eruptive mechanism
Fluoride acts directly at the erupted tooth surface by:
- inhibiting demineralisation by lowering the critical pH for dissolution of tooth enamel;
- enhancing the rate of remineralisation by lowering the energy needed for reformation of apatite crystals or calcium fluoride;
- inhibiting acid formation by microorganisms involved in caries formation; and
- interfering with the growth and metabolism of these same microorganisms at higher fluoride concentrations.

Pre-eruptive mechanism
Fluoride is ingested and incorporated into the developing tooth during mineralisation, favouring the crystallisation of larger and more regular fluorapatite crystals which are less susceptible to acid dissolution.

All sources of fluoride can act through both mechanisms. For instance, water fluoridation provides fluoride ions for developing and maturing teeth prior to eruption and at the tooth surface of erupted teeth. Similarly, toothpastes with fluoride provide fluoride ions at the tooth surface during brushing and by reflex or intentional swallowing for uptake into developing teeth. A landmark discussion (Fejerskov et al, 1981) and review (Beltran and Burt, 1988) have indicated that fluoride’s predominant mechanism of action is post-eruptive, by acting at the tooth surface/dental plaque interface.

What is dental fluorosis?
Dental fluorosis is a developmental defect of enamel that occurs when an excessive amount of fluoride is ingested during the period of enamel formation (between birth and six years of age). This results in increased porosity of the surface and subsurface enamel, causing the enamel to appear opaque. The severity of the defect depends on the amount of fluoride ingested, the duration of exposure, and the age(s) when exposure occurs. The relationship between fluoride intake and dental fluorosis in any one individual is not necessarily direct. Diet and conditions such as calcium deficiency can affect enamel development and whether dental fluorosis manifests or not. In general, however, higher fluoride intakes during the critical period of tooth development will result in more severe fluorosis (Burt, 1992).

Clinically, the appearance of dental fluorosis ranges from barely discernible, opaque or white flecks in its mildest form, through to total loss
of enamel in the most severe form. The very mild form is detectable by dental personnel and may be observed by others. However, more severe forms may be perceived as an aesthetic problem by children, parents and other observers (Riordan, 1993; Hoskin and Spencer, 1993).

Possible risk factors for dental fluorosis...

- fluoride from infant formula
- fluoride supplements
- ingested fluoride from toothpaste

Although adjusting the fluoride level in public water supplies from negligible to optimal levels of fluoride can be related to an increase in the prevalence of fluorosis, the cause of most of the increase in dental fluorosis in recent times is most likely sources other than water fluoridation. This has been demonstrated by the observation that, although the greatest fluorosis prevalence is in fluoridated communities, the greatest relative increase in fluorosis prevalence has been in communities with very low water fluoride concentrations. Sources of fluoride other than water fluoridation that have been implicated (Pendrys and Stamm, 1990) as possible risk factors for dental fluorosis include:
- fluoride from made-up infant formula;
- fluoride supplements;
- ingested fluoride from toothpaste.

Other risk factors, such as air pollution by fluoride and non-water based dietary fluoride, do not apply in Australia.

Infant formula

Research has indicated that some made-up infant formulas, when reconstituted with fluoridated water, could provide a daily fluoride intake above the suggested threshold for fluorosis (Silva and Reynolds, 1996). Further, increased duration in use of infant formula leads to a greater likelihood of dental fluorosis (Osuji et al, 1988).

It is possible to control the fluoride concentration of infant formula in the manufacturing process. This essential initial step is now carried out by the majority of Australian infant formula manufacturers. It is also possible to reduce the fluoride concentrations of infant formula by using non-fluoridated water in its preparation; some parents may use home rain water, filtered water or spring water for this purpose. However, non-fluoridated water is not readily available to many parents; therefore, the other means of reducing fluoride intake from infant formula at present include reducing the duration and intensity of formula feeding by emphasising breast feeding or the appropriate use of other fluids for feeding as an infant grows.

Fluoride supplements

Fluoride supplements were introduced as a fluoride water substitute for children in non-fluoridated areas, and are intended for use only in areas where there is little or no fluoride in the drinking water. The original dosages were recommended so as to supply 1.0mg of fluoride daily, with an adjustment for the lower body mass of children three years old or younger. The recommended dosages were further adjusted downward since the work of Aasenden and Peebles in 1974, which showed higher prevalence of fluorosis among children using fluoride tablets.

Since that time the extent and severity of caries has declined further and fluoride is being ingested from additional sources. It is likely that many young children are now ingesting 0.4–0.6mg fluoride per day from foods, beverages and toothpaste alone (Burt, 1992). These amounts are quite enough to cause dental fluorosis without adding more fluoride from a supplement.

“Fluoride supplements... are intended for use only in areas where there is little or no fluoride in the drinking water.”
Sources of fluoride

Prior to the 1960s, the main sources of fluoride were drinking water and food, which naturally contained varying concentrations of fluoride. From the late 1960s on, the fluoride concentrations of many water supplies have been adjusted to a level optimal for the prevention of dental caries. During the 1980s, numerous other sources of fluoride became available, including professionally applied and home care dental products containing fluoride (e.g. toothpastes and mouthrinses) and dietary fluoride supplements. Water fluoridation remains the most cost-effective method of fluoride delivery, providing the greatest benefit to those who can least afford dental health products and preventive dental care. In Australia concentrations ranging from 0.6ppm in Darwin to 1.1ppm in Hobart have been confirmed by the NHMRC as safe and effective.

Appropriate daily fluoride

Appropriate daily fluoride should maximise prevention of dental caries while limiting the risk of dental fluorosis. Although views are equivocal, a daily intake of fluoride ranging from 0.05 to 0.07mg per kilogram body weight in children is thought to be the lower boundary of intakes leading to fluorosis (Burt, 1992). Thus the total daily fluoride intake would vary from 0.2mg in an infant to 0.6mg in a two year-old child. Fluoride intake of children 22 to 26 months old is particularly important because the anterior permanent teeth are at the early maturation stage, during which they are particularly susceptible to fluoride-induced change (Evans and Stamm, 1991). However, over-exposure both before and after this age period may contribute to dental fluorosis.

Essentially, fluoride supplements have little impact on caries prevention in the presence of other fluoride sources, but present a clear risk of fluorosis (Leverett, 1991). For this reason, recommendations have been made to reduce the recommended schedules for fluoride supplements in industrialised nations.

Set out in Table 1 below are guidelines with reduced dosages as recommended by an NHMRC Expert Advisory Panel (1993). These schedules are interim recommendations and include changes to the age of initiation and dosages for specific ages.

Table 1
1993 recommended daily dosage of fluoride supplement (mg/day) according to fluoride concentration of drinking water (NHMRC)

<table>
<thead>
<tr>
<th>Concentration of fluoride in water supply (parts per million)</th>
<th>Age</th>
<th>&lt;0.3</th>
<th>0.3-0.5</th>
<th>&gt;0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mths - 4 years</td>
<td></td>
<td>0.25</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>4 - 8 years</td>
<td></td>
<td>0.50</td>
<td>0.25</td>
<td>0.00</td>
</tr>
<tr>
<td>8 years +</td>
<td></td>
<td>1.00</td>
<td>0.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Source: NHMRC, 1993</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fluoride-containing dentifrices

Studies have indicated that prior to the age of five or six years, children swallow, rather than expectorate, much of the dentifrice with which they brush (Barnhart et al, 1974; Naccache et al, 1992). For instance, approximately 65 per cent of toothpaste used may be ingested by a two year-old, 50 per cent for three and four year-olds and just over 30 per cent for 7 year-olds (Barnhart et al, 1974).

Ripa (1991) has estimated from existing studies that the average amount of fluoride ingested by a pre-school child, brushing twice daily with a standard-strength toothpaste (1000-1100ppmF) was 0.268mg. Thus the inadvertent swallowing of toothpaste has to be seen as a measurable part of daily fluoride intake and, when swallowed by young children, standard concentration fluoride toothpaste should be considered a potential risk factor for dental fluorosis.

Findings such as these have led to a recent emphasis on both lowered fluoride concentration toothpaste for children and guidelines for the use of toothpaste by children (Horowitz, 1992). The efficacy of a lower fluoride concentration toothpaste (say 400ppm) may be marginally lower; however, a contemporary diet and lifestyle may work toward an equivalent low caries activity. In addition, the risk of fluorosis will be reduced (Holt et al, 1994). It is important however, to continue to reinforce guidelines for the use of all toothpaste by children, as inappropriate use of any toothpaste could put a child at risk.

“when swallowed by young children, standard concentration fluoride toothpaste should be considered a potential risk factor for dental fluorosis.”
Guidelines for toothpaste use by children

- The age of initiation of toothpaste use should be delayed to approximately two years of age.
- Parents should supervise the use of toothpaste and toothbrushing by their children until six years of age.
- Toothbrushes with small heads should be used by children.
- Only a smear of toothpaste should be dispensed onto the head of the toothbrush (parents should apply the toothpaste themselves until the children can do it properly).
- Children should be discouraged from eating or swallowing toothpaste after brushing.
- Toothpaste tubes should be kept out of the reach of children.
- Parents should be encouraged to use a low fluoride toothpaste for their children such as My First Colgate toothpaste.

Dietary sources of fluoride are the least easily controlled of all the major fluoride sources, and thus the major focus should be on limiting excessive ingestion of fluoride toothpaste by young children and following the adjusted 1993 recommended dietary fluoride supplement dosage schedule. It is important therefore that a concerted effort be made by all dentists to follow the fluoride supplement recommendations and to educate parents with young children in the proper use of fluoride toothpaste and infant formula. Such efforts should ensure continued substantial dental caries prevention without increased risk of dental fluorosis.

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References