



Review Article

A Review of the Uses of Fluoride and Outcomes of Dental Caries Control in Singapore

Gabriel Tse Feng Chong and Patrick Tseng

Dental Branch, Manpower Standards and Development Division, Ministry of Health, Singapore.

Abstract

In 1958, Singapore was the first country in Asia to implement a community water fluoridation program covering 100% of its population. There were no reports of anti-fluoridation activities or calls for referenda then; and at present, there is only mild opposition to water fluoridation. The water was initially fluoridated at 0.7 ppm but was gradually adjusted downwards to 0.6 ppm in January 1992, with a further reduction to 0.5 ppm in January 2008 where it has since remained unchanged. Fluoride varnishes and gels are also available for use by the professional for judicious application in individuals who are at high-risk of dental caries. In addition, fluoridated dentifrices and mouth rinses are also readily available over the counter for home use.

In addition to the use of fluorides, the following factors also contribute to the high level of oral health in Singapore: (i) a highly educated populace; (ii) public health education to increase awareness and literacy is routinely carried out by the Health Promotion Board; (iii) the School Dental Service provides 'free' dental care to school children up to 18 years of age; and (iv) primary dental care is also readily accessible by the general public by an extensive network of private and public sector dental clinics. [*Singapore Dent J* 2011;32(1):14–18]

Key Words: dental caries, fluoride, Singapore, water fluoridation

Introduction

Singapore is a small and compact island nation measuring 710.2 km² lying off the southern tip of Peninsular Malaysia. Its total population stands at 5.08 million comprising 74.4% (3.77 million) residents and 25.6% (1.30 million) of an expatriate workforce.¹

With no natural resources of its own, Singapore relies primarily on its strategic location and manpower for economic growth. Its major industries are finance, trade, manufacturing, and tourism and more recently information technology and biomedical research and development.

Today the nation is ranked among the top 10 global cities in the world alongside New York, London, Tokyo, Hong Kong, and Sydney in terms of economic, political, cultural, and infrastructural development.² WHO has also ranked Singapore's healthcare system the sixth in the world based on overall health system performance.³

Singapore's current per capita GDP is US\$36,537 and has a healthcare budget of 4.0% of the GDP. Dental healthcare, however, comprises only 2.5% of the overall healthcare budget.

This article reports on the uses of fluoride in Singapore, outcomes in dental caries control, and challenges that lie ahead.

Correspondence to:

Assoc Prof Patrick Tseng, Dental Branch,
Manpower Standards and Development Division,
Ministry of Health, College of Medicine Building,
16 College Road, Singapore 169854.
E-mail: patrick_tseng@moh.gov.sg

Note: This manuscript is adapted from a conference paper presented at the Workshop on "Effective Use of Fluoride in Asia" organized by The Dental Association of Thailand, Thammasat University, WHO, FDI and IADR in Phang-Nga, Thailand from 22 to 24 March 2011.

Community Water Fluoridation

Loh⁴ reported that the prevalence of dental caries in school children was as high as 95% in the 1940s and early 1950s. The School Dental Service was established in 1949, in response to the high unmet dental needs of school children.⁴ There were few dentists in Singapore in the early 1950s and dental auxiliaries (similar to the New Zealand type school dental nurse) were employed in the School Dental Service to provide cost-effective primary dental care.⁴ The School Dental Service currently provides heavily subsidized dental treatment to all school going children 6–18 years of age.

The authorities at that time realized that the enormity of the scope presented by the prevalence of dental caries could not be managed by a purely restorative/curative approach.⁴ Discussions to fluoridate the water supply were undertaken in the mid-1950s and the decision to implement water fluoridation was approved by the government in 1954. Fluoridation was first implemented on an experimental basis in May 1956 and by January 1958, the entire water supply of Singapore was fluoridated. There were no reports of anti-fluoridation activities or calls for referenda then.⁴

Singapore was the first country in Asia to implement a community water fluoridation program covering 100% of its population.⁴ With universal coverage via a municipal water supply (in Singapore the Public Utilities Board is the only water utility), Singapore did not have to depend on other communal forms of fluoride delivery.

Based on the formula derived by Galagan and Vermillion,⁵ Singapore's water was initially fluoridated at 0.7 ppm using a dry feeder distribution system and sodium silicofluoride as the derivative fluoride compound.⁴ A 1989 study on the developmental defects of enamel (DDE) including fluorosis was conducted on 2,090 children aged between 11 and 13 years.⁶ In this sample, it was reported that 83.3% of the children used fluoridated toothpaste before reaching 6 years of age; while 61.9% had no or questionable fluorosis, 26.6% had very mild fluorosis, and 10.5% mild fluorosis. This was a huge increase from the earlier findings of 1970, when it was reported that less than 5% of children had a very mild form of fluorosis.⁷ The Community Fluorosis Index (CFI) based on the 1989 study⁶ was 0.56,

which was deemed to be bordering on a CFI of 0.60 (which may warrant consideration as a public health concern).⁴

The results of this study on DDE and fluorosis together with reports from the downward adjustment of the levels of fluoride in Hong Kong's drinking water from 1.0 ppm in 1967 to 0.7 ppm in 1978, and finally to 0.5 ppm in 1988 prompted the Ministry of Health to lower the fluoride levels from 0.7 to 0.6 ppm as of January 1992⁴ and a further reduction to 0.5 ppm since January 2008 where it has remained unchanged. Since its implementation, water fluoridation has been the mainstay caries preventive measure in Singapore.

Professionally Applied Fluoride Products

Local guidelines concerning the use of professionally applied fluorides are similar to international practices, which is the judicious and selective use of these fluoride vehicles for patients at high risk of dental caries. These professionally applied fluoride vehicles include fluoride varnishes and gels. However, silver fluorides/silver diamine fluorides are not available locally and these have to be specially ordered from foreign vendors when required. Fissure sealants are also routinely placed for high risk children in the School Dental clinics which provide 'free' dental services to all (100%) school going children between 6 and 18 years of age.

Unfortunately, there are no local data on the availability, accessibility, affordability, and acceptability or coverage of the professionally applied and self-use forms of fluoride.

Self-use Fluoride Products

Fluoridated toothpastes and mouthrinses are available for self-use in Singapore and an empirical observation suggests that the majority of dentifrices are fluoridated. However, some manufacturers have increasingly marketed non-fluoridated toothpastes containing other "substitute" proprietary ingredients such as chlorhexidine, triclosan, and even green tea.

Some South Asian migrants still use traditional cleaning powders or pastes instead of fluoridated toothpastes. This number could possibly increase

Table 1. Uses of fluoride in Singapore

Type of fluoride regime	Name of fluoride vehicle	Current status
Community	Water fluoridation	100% coverage since 1958
	Milk fluoridation	NA
	Salt fluoridation	NA
Professionally applied	Fluoride varnishes	Available
	Fluoride gels	Available
	Silver fluorides/silver diamine fluorides	Not available locally, individual professionals have to order from overseas
Self-use by individuals	Fluoridated toothpastes	Available
	Fluoride mouthrinses	Available
	Fluoride supplements	NA

with the increasing number of immigrants from the Indian subcontinent.

The Health Science Authority (HSA) of Singapore has also set guidelines regarding the maximum concentration of fluoride that can be present in dentifrices that are imported into Singapore. Toothpastes available can be divided into those for children and those for adults based on the content of fluoride concentration.

Currently, the product with the highest concentration of fluoride available “over-the-counter” locally is Colgate’s Neutrafluor 220 Daily Fluoride Rinse (0.05% w/w neutral sodium fluoride). Toothpastes with much higher concentrations of fluoride (i.e. 5,000 ppm) are not available; however, there are ongoing discussions with the relevant health authorities to introduce Neutroflor toothpaste (5,000 ppm, marketed by Colgate) into Singapore. Table 1 shows the various forms of fluoride available in Singapore.

Outcomes in Dental Caries Control

In 1957, a baseline study was carried out before the implementation of water fluoridation.⁷ The study comprised annual surveys conducted over a 10-year-period to evaluate the effect of water fluoridation on dental caries. Children in the control group were selected from schools in unfluoridated Malacca, West Malaysia. Each year, 2200 Malay and Chinese children aged between 7 and 9 years were selected from Singapore and Malacca.

The results showed a 30.8% decline in primary dentition caries experience among the Singapore

children, whereas there was no corresponding decline observed among the Malaccan (control) group.⁷ For permanent dentition, the Malaccan Malays experienced a 63.1% increase in caries experience compared with a 31.0% decrease among Singaporean Malays. On the other hand, Malaccan Chinese children showed a 21.6% increase in permanent caries experience compared to their Singaporean peers who experienced a reduction of 52.3%.⁷ The greater reduction in caries experience observed among the Chinese was reported to be due to the higher prevalence of dental caries over their Malay counterparts.⁷

Subsequent surveys by various authors have reported steadily declining dental caries experience in school children aged between 6 and 18 years. A composite of these various findings are shown in Table 2. For example, Lo and Bagramian⁸ reported that sequential school dental surveys carried out by the Ministry of Health showed an increase in the proportion of children free of caries in the permanent dentition from 30.0% in 1970 to 58.7% in 1994. There was also a decline in mean DMFT from 2.60 to 1.08 for school children aged 6–11 years and the mean DMFT had decreased from 2.98 in 1970, 2.61 in 1979, 1.97 in 1984, 1.61 in 1989 to 1.05 in 1994.¹⁰ In each of these surveys, approximately 5000 school children aged 6–18 years were examined and this sample size represented 1.2% of the school going population.⁸ The latest survey carried out by the Health Promotion Board in 2003 on the dental caries prevalence of school children in Singapore found the DMFT for 12-year-olds to be 0.54.⁹

However, the success in caries control among Singaporean school children is not seen in

Table 2. Mean dmft and DMFT scores for various age groups in Singapore by chronology

Age (years)	Year	Mean DMFT	Source*
5 (preschool) (dmft)	2005	2.03	6
6 (dmft)	1970	0.41	4
	1979	0.39	4
	1984	0.15	4
	1989	0.13	4
	1994	0.09	4
6–11 (DMFT)	1970	2.6	10
	1979	2.1	10
	1984	1.9	10
	1989	1.3	10
	1994	1.1	10
12 (DMFT)	1970	2.97	4
	1979	2.84	4
	1984	2.47	4
	1989	1.39	4
	1994	0.98	4
	2003	0.54	5
12–18 (DMFT)	1970	4.6	10
	1979	3.8	10
	1984	3.2	10
	1989	2.5	10
	1994	1.6	10

*Numbers refer to reference citations from the reference list (e.g. 4 refers to Loh, 1996).

pre-schoolers as suggested by a recent examination of 1782 pre-schoolers aged 3–6 years carried out in 2005 by Gao et al.¹⁰ The authors found that about 40% of the study group had dental caries. The mean DMFT (SD) among 3–4, 4–5, and 5–6-year-olds were 0.70 (1.78), 1.40 (2.68), and 2.03 (3.07), respectively. This study also found that 16% of the children carried 78% of the burden of disease and that 16.5% of children suffered from rampant caries (defined in the study as caries affecting smooth surfaces of two or more maxillary incisors).

The authors of the study attributed their findings to the “plateau effect of water fluoridation and insufficient organized dental services and oral health promotion for the pre-schooling population.” The authors therefore suggested extending

the School Dental Service to pre-schoolers, particularly those at a high-risk of dental caries.¹⁰

In addition, Gao et al.^{10,11} also reported that higher caries experience and unmet treatment needs were found among children of lower socioeconomic status (Social Economic Status proxies used were parental education level and children living in public housing units, HDB apartments) and the indigenous population (Malays). They attributed the racial and socioeconomic difference in caries severity to differences in: (i) poor oral health practices/behaviours (such as prolonged breastfeeding, night time bottle feeding, cariogenic diet); (ii) dental awareness and knowledge of parents and caregivers; (iii) cultural, ethnic and religious norms and beliefs (i.e. how people of different ethnicities prioritize their resources, how attentive and receptive they are to health education messages, and how they synthesize and comprehend these information); and (iv) barriers to assessing oral healthcare services faced particularly by the disadvantaged.

Lessons Learned and Future Challenges

Singapore is fortunate that water fluoridation has been in place for over half a century and there have been no reports of opposition to this public health measure at the onset of its implementation.⁴ In recent years, however, opposition to water fluoridation has increased probably due to a better educated and well-travelled populace that has found its political voice and the myriad of anti-fluoridation material that is readily accessible off the internet (water fluoridation hardly receives any media attention in Singapore). It is hoped that the lukewarm or mild opposition to fluoridation would remain the same in time to come as the overall political atmosphere of the populace is fairly muted.

In line with systematic reviews and audits of all governmental policies, the Ministry of Health has set up a fluoride review committee whose objective is to monitor and conduct reviews on the fluoridation of drinking water by: (i) determining the appropriate and safe concentration levels of fluoride to maintain in Singapore’s drinking water in order to achieve optimal effectiveness against dental caries; (ii) determining

the estimated daily fluoride exposure per individual; and (iii) debating the need for mandatory fluoridation of the drinking water supply.

It is highly unlikely that water fluoridation would be reversed and the role of the committee is more to review the contemporary literature as is required of good public health practices.

Generally, the levels of oral health in Singapore are good and are comparable to other developed countries. Singapore is fortunate to have enjoyed universal coverage of water fluoridation for over 50 years. The population is also highly educated and health awareness is generally high. The School Dental Service provides 'free' dental care to school children up to 18 years of age. Furthermore, primary dental care is also readily accessible by the general public. Twenty-five percent of primary dental care is provided through public sector community clinics (polyclinics), which are heavily subsidized by the government, whereas the remaining 75% is provided by an extensive network of private general practice clinics found across the island. Moreover, public education to increase awareness and literacy of healthcare issues are also routinely carried out by the Health Promotion Board.

The challenges facing Singapore are:

1. Addressing the inequality of dental caries—a burden that is mainly carried by members of lower socioeconomic groups and the indigenous population.
2. Addressing the high dental caries experience among pre-schoolers.
3. With the government's policy of attracting foreign talent and the resultant rapid influx of immigrants, it is expected that the prevalence of dental caries would increase and there is a need to look into the provision of accessible and affordable dental care and services.
4. Fine tune the current healthcare delivery system to ensure that the less fortunate, elderly, and those with special needs are not deprived of accessing oral healthcare services.
5. More effective inculcation of good dental homecare and dietary habits by the public in view of the popularity of fizzy and sports drinks consumed by many Singaporeans.

Some suggestions that have been advocated by Gao et al.¹¹ to overcome the racial and socioeconomic inequality in oral health among pre-schoolers are: (i) professionals should provide specific tailor-made advice rather than generic ones with respect to oral health behaviors and seeking dental services; (ii) public literacy programs to advocate increased dental attendance; (iii) addressing barriers to accessing dental services that are faced by disadvantaged communities; and (iv) understanding the health-related values and lifestyles of the different target population in a multi-ethnic society (i.e. the frequent intake of sweet deserts in the Malay community).

References

1. Ministry of Health. *Statistics. Health Facts Singapore*. Available at: <http://www.moh.gov.sg/mohcorp/statistics.aspx?id=240> [Accessed February 15, 2011].
2. Wikipedia. *Global City*. Available at: http://en.wikipedia.org/wiki/Global_city [Accessed February 15, 2011].
3. WHO ranking of countries by healthcare systems. Available at: <http://www.photius.com/rankings/healthranks.html> [Accessed August 15, 2010].
4. Loh T. Thirty-eight years of water fluoridation—the Singapore scenario. *Community Dental Health* 1996; 13(Suppl 2):47–50.
5. Galagan DJ, Vermillion JR. Determining optimum fluoride concentration. *Public Health Rep* 1957;72: 491–3.
6. Loh T, Chan J, Low CN. *Survey of developmental defects of dental enamel in Singapore 1989*. Singapore: Ministry of Health, Dental Division, 1990.
7. Wong MQ, Goh SW, Oon CH. A ten study of fluoridation of water in Singapore. *Dental J Malaysia Singapore* 1970;10:1–15.
8. Lo GL, Bagramian RA. Declining prevalence of dental caries in school children in Singapore. *Oral Dis* 1997; 3:121–5.
9. Health Promotion Board. *The Children Oral Health Survey 2003*. Singapore: Health Promotion Board, 2003.
10. Gao XL, Hsu CYS, Loh T, Koh D, Hwang HB, Xu Y. Dental caries prevalence and distribution among preschoolers in Singapore. *Community Dental Health* 2009;26:12.
11. Gao XL, Hsu CYS, Xu YC, Loh T, Koh D, Hwang HB. Behavioral pathways of oral health disparity in children. *J Dental Res* 2010;89:985–90.