Survey of fluoride levels in vended water stations

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This study sought to measure the fluoride concentration of water derived from vended water stations (VWS) and to identify its clinical implications, especially with regard to caries prevention and fluorosis. VWS and corresponding tap water samples were collected from 34 unique postal zip codes; samples were analyzed in duplicate for fluoride concentration. The average fluoride concentration in VWS water was significantly lower than that of tap water ($P < 0.001$). Fluoride concentration in the VWS water ranged from <0.01 ppm to 0.04 ppm, with a mean concentration of 0.02 ppm (±0.02 ppm). Patients utilizing VWS as their primary source of drinking water may not be receiving optimal caries preventive benefits; thus dietary fluoride supplementation may be indicated. Conversely, to minimize the risk of fluorosis in infants consuming reconstituted infant formula, water from a VWS may be used.

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Community water fluoridation has been hailed as one of the 10 most successful public health achievements for its benefit in preventing dental caries.[1] Initial implementation of optimally fluoridated drinking water in the mid-twentieth century United States, ranging from 0.7 to 1.2 ppm fluoride, demonstrated reductions in caries of 55% to 60%.[2-3] By the end of the millennium, the US Centers for Disease Control and Prevention reported a reduction in caries of approximately 25% due to water fluoridation.[4]

Despite the success of community water fluoridation in reducing dental caries, not all patients in the US have access to optimally fluoridated water. As of 2010, approximately 66.2% of the US population received fluoridated water in their home.[5] Furthermore, dental caries continues to be one of the most prevalent chronic diseases.[6] Contrary to the continuing public health need to prevent dental caries and the proven efficacy and cost-effectiveness of employing water fluoridation to do so, there is a growing trend amongst our patients to seek alternatives to the consumption of fluoridated community water.[7]

Perhaps the most well-known drinking water alternative is bottled water. In 2012, almost 9.7 billion gallons of bottled water were consumed in the US; this represents nearly twice the 5 billion gallons reported in 2000 (which, in turn, was double the consumption of a decade earlier).[8,9] Some patients drink bottled water for fear that tap water might be unsafe for consumption.[10] Others may drink bottled water for perceived status or as a healthy alternative to soft drinks.[11,12] Regardless of the reason, it seems that more and more of the patient population is drinking bottled water, which is known to have suboptimal fluoride concentration.[13,14]

An emerging source of drinking water is the self-serve vended water station (VWS). Often housed inside or near grocery retailers, these stations accept direct insertion of payment from the consumer. The consumer is then able to fill his/her own containers with an automated and controlled quantity of water. One prominent vendor of these stations is Glacier Water (Glacier Water Services, Inc.). Water from this vendor is advertised as economical, pleasant tasting, and clean, due in part to a multiple filtration system housed in each VWS.[15] Because of its low fluoride concentration, patients who drink primarily bottled water are likely to miss out on the caries-preventive effect of fluoridated tap water, as bottled water companies regularly utilize various forms of filtration in the production process. If water from a VWS is similarly filtered, then the expectation would be that fluoride concentrations in vended water would be similarly minimal. To the authors' knowledge, no previous study has been published regarding the fluoride concentration of water from a VWS. Thus, the purpose of this study was to test the null hypothesis that water from a VWS will show no significant difference in fluoride concentration from tap water in the same postal zip code, as well as explore the ramifications in the prevention of dental caries.

Materials and methods

Water samples from 34 zip codes were collected in separate sealable 15 ml polystyrene conical tubes (Becton, Dickinson and Company) in Harris County, Texas. The zip codes were chosen based on geographic spread and the presence of a Glacier Water station. A sample was collected from 1 Glacier VWS located in each of the chosen zip codes in Harris County. Also, tap water samples were collected from each zip code. The tap water sample for each zip code—collected on the same day as the self-serve VWS sample—was collected from inside the venue/facility (bathroom or public area) where the VWS was located. Thus, for each zip code, a pair of water samples was collected: 1 VWS sample and 1 tap water sample. With these 34 pairs (resulting in 68 total samples), 80% power to detect a medium effect size of $[d] = 0.50$ was obtained. For fluoride concentration measurements, each of the 68 samples were diluted with Orion TISAB II buffer (Thermo Fisher Scientific, Inc.) and then analyzed with an Orion fluoride-specific electrode and millivolt-meter (Model 701A, Thermo Fisher Scientific, Inc.) in duplicate. The fluoride concentrations for each duplicate sample pair were averaged, and data analysis was performed utilizing a t-test for paired comparisons.

Results

The t-test determined that the average difference in fluoride concentration between VWS and tap water samples to be statistically significant ($P < 0.001$).

Table 1. Vended water station and tap water fluoride concentrations (ppm) by US zip code.

Zip code	Vended water station fluoride concentration	Tap water fluoride concentration
77004	0.02	0.69
77005	0.02	0.79
77008	0.02	0.52
77009	0.02	0.50
77015	0.01	0.47
77019	0.01	0.84
77021	0.02	0.71
77022	0.01	0.51
77023	<0.01	0.68
77024	0.01	1.02
77025	0.01	0.84
77029	<0.01	0.50
77030	<0.01	0.73
77031	<0.01	0.60
77033	<0.01	0.70
77034	<0.01	0.58
77035	<0.01	0.66
77038	<0.01	0.18
77039	0.01	0.33
77041	0.01	0.47
77056	<0.01	0.62
77081	0.04	0.73
77051	0.02	0.66
77054	0.01	0.68
77055	0.01	0.56
77057	<0.01	0.80
77063	<0.01	0.57
77067	<0.01	0.34
77070	<0.01	0.18
77077	0.03	0.55
77037	0.02	0.51
77093	0.01	0.60
77095	0.01	0.59
77096	0.03	0.63

Table 2. Dietary fluoride supplement schedule.[17]

	Fluoride ion level in drinking water (ppm)[a]		
Age	<0.3 ppm	0.3 – 0.6 ppm	>0.6 ppm
Birth – 6 months	None	None	None
6 months – 3 years	0.25 mg/day[b]	None	None
3 – 6 years	0.50 mg/day	0.25 mg/day	None
6 – 16 years	1.0 mg/day	0.50 mg/day	None

[a]1 ppm = 1 mg/l
[b]2.2 mg sodium fluoride contains 1 mg fluoride ion

The mean difference between tap water fluoride concentration and VWS fluoride concentration was 0.58 ppm (with a 95% confidence interval) for the recorded differences that ranged from 0.52 ppm to 0.64 ppm. The range of fluoride concentration in the tap water was 0.18 ppm to 1.02 ppm, and the mean concentration of fluoride was 0.60 ppm (±0.18) (Table 1). The range of fluoride concentration in the VWS water ranged from <0.01 ppm to 0.04 ppm, and the mean concentration of fluoride was 0.02 ppm (±0.02).

Discussion

The mean fluoride concentration of water samples derived from the Glacier VWS in this study was 0.02 ppm, which is well below the recommended optimal fluoridation level of 0.70 to 1.20 ppm.[2] Based upon these results, patients that primarily consume vended water are not ingesting optimally fluoridated water. The mean fluoride concentration of the VWS water samples was significantly lower than the mean fluoride concentration of the tap water samples. Thus, the null hypothesis that there is no significant difference in fluoride concentration between VWS and tap water samples was rejected.

The discrepancy between fluoride concentrations in VWS samples and tap water samples from the same zip code is most likely due to the filtration methods utilized by the Glacier VWS. Per the manufacturer's website, each Glacier VWS takes local tap water and processes it through the following steps: activated carbon filter, micron filter, reverse osmosis, postcarbon filter, and ultraviolet light.[15] Although carbon filtration may remove some fluoride content from water, of particular interest is reverse osmosis.[12] Reverse osmosis applies pressure to water through a selective membrane to aid in removal of minerals, among them fluoride.[12] Indeed, the Glacier Water website cites reverse osmosis as the component that removes "salts and impurities." It may be concluded that any water that has been filtered by reverse osmosis, whether VWS, bottled, or in one's home tap, will experience a reduction in fluoride concentration.

Results from this study pose several challenges for the practicing dentist. First, with regard to the minimal fluoride concentrations in water from a VWS, if a patient's primary source of hydration is from a VWS, then that patient is not deriving the maximum anticaries benefit from his/her drinking water. It has been well established that the primary mode of action of fluoride in preventing caries is topical protection in small quantities on a daily basis, optimally fluoridated drinking water certainly fits this description.[1] Indeed, fluoridated drinking water is considered a protective factor when determining caries risk status, and the absence of optimally fluoridated water increases caries risk.[16]

Based on the caries risk level, age, and fluoride concentration of drinking water, the current evidence still points to the supplemental prescription of dietary fluoride for some pediatric patients (Table 2).[17] The low concentrations of fluoride in alternative drinking water sources, such as VWS and bottled water, make it imperative that the dental practitioner know the primary source of a patient's drinking water.

The indication for judicious prescription of dietary fluoride supplements, based in part on drinking water fluoride concentration, is related to the second implication of the results from this study. Tap water samples in this study demonstrated fluoride concentrations ranging from 0.18 to 1.02 ppm, averaging 0.60 ppm. Thus, on average, even tap water samples in this study fell below the recommended minimum (0.70 ppm) fluoride concentration for an optimal anticaries effect; such a wide variation in tap water fluoride concentration may create challenges for accurate prescription of dietary supplements. It has been reported that even within the same region, there can be geographical and chronological fluctuations in tap water fluoride concentration.[18-20] In light of this, a practitioner who is collecting tap water samples from a patient to determine whether dietary fluoride supplementation is needed should collect multiple water samples over a span of time, and communicate with local water authorities to better understand that community's drinking water fluoridation methods and trends.

Fluorosis is the primary concern for a patient who overconsumes fluoride, whether from an inappropriate supplemental prescription or other forms of ingestion. Dental fluorosis is the disruption of enamel formation when systemic fluoride incorporates into the enamel structure of a tooth bud during development; thus, the most susceptible population for fluorosis is children. Fluorosis can manifest in faint white spots or brown pits.[21,22] Although fluorosis is considered primarily an esthetic condition, the recommendations for optimal fluoridation of water (0.7-1.2 ppm) aim to maximize caries prevention and minimize fluorosis risk. Therefore, all of the VWS samples and some of the tap water samples from this study offered minimal caries prevention potential; conversely, if a patient drinking optimally fluoridated water mistakenly received a prescription for dietary fluoride supplementation, risk for fluorosis increases. A challenging balance must be sought by both practitioner and patient.

The desire to minimize fluorosis has implications for an especially vulnerable population: infants. Although it is recommended that infants consume breast milk for optimum nutrition, the primary diet for many babies consists of formula. Varieties of infant formula that are sold as powder or liquid concentrate need to be reconstituted with water before consumption. Powder and liquid concentrates of formula inherently contain fluoride; reconstitution with optimally fluoridated water may actually result in overconsumption of fluoride by the infant, thus increasing the risk for fluorosis.[23] If there is concern with regard to overconsumption of fluoride from the use of infant formula, the practitioner may recommend a low fluoride source of water for the reconstitution of the formula. VWS or distilled bottled water will likely be safe alternatives to fluoridated tap water in this circumstance.[13]

Conclusion

This study found that water sourced from a VWS on average contains well below the fluoride concentration range recommended for the prevention of dental caries. Patients utilizing these stations as their primary source of drinking water are likely missing out on the caries preventive benefits of optimally fluoridated tap water.

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