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THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: Evaluation of point-of-use filters and the impact on fluoride concentration

Name of Candidate: CPT Jessie Gregg
Degree: Master of Science
Date: June 30, 2023

THESIS/MANUSCRIPT APPROVED: SIGNATURE/DATE:

Dr. Garrett Wood, LTC, DC
Chief of Orthodontics, Fort Bragg, NC
Research Advisor/Committee Member

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Dr. Caroline Mikaloff, MAJ, DC
Assistant Director, AEGD-2, Fort Bragg
Committee Member

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Dr. Erik Reifenstahl, LTC, DC
Program Director, AEGD-2, Fort Bragg
Committee Chairman

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Evaluation of point-of-use filters and the impact on fluoride concentration

CPT Jessie Gregg, DDS
2-Year AEGD
Fort Bragg, NC
Mentor: MAJ Caroline Mikaloff
Research Proposal

Background:

According to the Center for Disease Control and Prevention (CDC) the United States has one of the safest water supplies in the world with 90% of Americans getting their water from community water systems (5). Community water systems are subject to regulations set forth by the Safe Drinking Water Act (5). The Environmental Protection Agency (EPA) requires a consumer confidence report (CCR) be delivered to the consumer no later than July 1 of each calendar year. This CCR has the most recent water source assessment information and a brief summary of the system's susceptibility to potential sources of contamination. The EPA sets legal limits on over 90 contaminants in drinking water (10). Despite guidelines, regulations, and frequent testing, contamination can still occur (10). Possible sources of contamination include the following: sewage release, naturally occurring chemicals and minerals, local land use practices (fertilizers/pesticides), manufacturing processes, manufacturing on-site waste water treatment systems, improperly treated water, and improperly maintained water distribution systems. Widespread water filtration started in the 1890's and has contributed to the drastic decrease in mortality due to waterborne disease (10). Roughly 100,000 people in the US get sick from foodborne, waterborne, and enteric illness combined each year, according to National Outbreak Reporting System (NORS) (10).

Literature suggests socioeconomic status impacts the type of water consumed. In 2007-2010, those with higher education and income were more likely to use water treatment devices (21), whereas adults with less education and lower income were more likely to drink bottled water. The decision to drink tap water, bottled water, or filtered water can be influenced by many factors including the perception of the water source, quality, and safety (21).

The addition of fluoride to the water supply is better known as community water fluoridation (CWF), and is recognized by the CDC as one of the ten great public health achievements of the twentieth century (6). CWF started in 1945 and has played an important role in the prevention of dental caries in children and adults (8). The daily presence of fluoride in saliva and plaque interrupts the caries-development process by preventing demineralization and enhancing remineralization of enamel (12).

Dental fluorosis, a condition that changes the appearance of tooth enamel, is the result of an overexposure to fluoride during tooth formation (7). The risk and severity of this condition depend on the dose, duration, and timing of the exposure (7). Mild cases are most common and can appear as faint while spots or striations (7). The much less common moderate and severe cases result in more extensive changes such as pitting or dark brown stains (7). In January 2011, the United States Public Health Service (USPHS) reviewed scientific information on whether or not water fluoridation continued to provide health benefits while minimizing the unwanted health effects of too much fluoride. Based on the results from that review the EPA, CDC, and ADA now recommend 0.7mg/L as an effective amount to decrease dental caries prevalence and severity, while reducing the risk of dental fluorosis (4,22). Community water fluoridation remains one of the most cost effective, equitable and safe means of providing protection against caries (9).

Disparities in caries prevalence among low-income families remains a constant problem. The prevalence of caries in these groups decreased from 72% in 1988-1994 to 66% in 1999-2004. The percent of U.S. population receiving fluoridated water increased from 56% to 62% between 1992 to 2004, representing an increase of more than 36 million people (22). However even with a decrease in caries due to community water fluoridation (CWF) opposition is still prevalent (23).

Due to communities' lack of trust in their water supplies, risk of possible water contamination, and opposition to CWF it is not surprising that people are turning to water filtration devices. Technological developments over the last ten years have allowed water filtration devices to advance. New filtration systems on the market have changed the method they use to filter water. Commonly used home filtration systems are point-of-use filters. Point-of-use filters are widely used due to the ease of access and low cost. They typically come in the form of a pitcher and can be easily purchased online or at most department stores.

Many companies manufacture point-of-use filters which include: Zero Water, Brita, and Pur. Zero water is a five-step ion exchange filtration system which claims to remove 99% of fluoride from the water (27). The standard filters from Brita incorporate multiple processes to filter water. First, water flows through a built-in mesh screen, then through activated carbon granules and lastly through an Ion Exchange Resin. Brita claims to "leave a healthy amount of fluoride" yet does not define that amount (25). Pur's Mineral Core™ Filter Technology claims "to provide superior filtration performance and innovation, by using activated carbon and ion exchange to reduce contaminants (26)." Pur does not comment on its filters effect on fluoride concentration (26).

Prior studies have shown conflicting results concerning the impact on fluoride through point-of-use filtration systems. Eftekhar B., et al found that water filtration significantly decreases fluoride concentration, while Konno H., et al reported that activated carbon filters do not remove fluoride from tap water (9,15).

Objective:

To measure the effect of point-of-use water filtration on fluoride concentrations in drinking water.

Hypothesis:

H_o: There is no statistically significant difference between the fluoride concentration before and after filtration with Zero water, Brita, or Pur water filtration systems.

Methods and Materials:

Overview:

The fluoride concentration of tap water from Fort Bragg, North Carolina was measured before filtration and after filtration in three different point-of-use water filtration systems using Apera Instruments WS200 Fluoride Meter.

Three common household point-of-use filters were compared. Each point-of-use filter uses a multi-step process to remove contaminants from water. The standard filter from Brita is a 3-step process. The first step is physical filtration using a mesh screen, the second step is a carbon filter and the third step is an ion exchange resin. The Pur Basic filter utilizes a "Mineral Core" which is composed of both activated carbon and an ion exchange. A five-step ion exchange process is utilized by Zero Water's Ready-Pour. The basic model from each brand was employed.

Each pitcher was washed in soap and rinsed thoroughly with water, then inverted and set aside until completely dry. Manufacturer's instructions were used to properly configure each filtration system. Water samples were collected from a single tap water source in Fort Bragg, North Carolina. One-hundred twenty (120) 5mL specimens were collected and placed in clean glass containers. In turn, these specimens were divided into three groups of forty. The aforementioned water samples were assigned to individual filtration systems. Two specimens from each group were left untreated (i.e., unfiltered), and thereby served as control measurements. Thirty-eight samples were tested using one filter per filtration unit. Fluoride levels for these samples were measured and recorded. Subsequently, the remaining samples were filtered using the system to which they were assigned. Fluoride levels for individual post-filtration specimens was measured and recorded (as described for control specimens). All measurements were accomplished using a WS200 fluoride meter (Apera instruments, Columbus, OH). The meter will be set up according to manufacturer's instructions and will be tested using a standardized fluoride solution to confirm accuracy.

Data analysis:

Data was screened for normality and homogeneity of variance using the Shapiro–Wilk statistic and Levene's test, respectively. Measures of central tendency and dispersion are reported as means with associated standard deviations. Paired-samples T Tests were used to test for pre/post-filtration changes in fluoride concentration for each of the filter brands. To evaluate between brand differences in fluoride concentration, a one-way analysis of variance (ANOVA) was used. Post hoc tests assessed significant differences between the filtration systems using the Tukey test. A value of $P < 0.05$ was considered significant for all tests. All data was analyzed with the IBM SPSS version 25 (IBM Corporation, Armonk NY, USA).

Results:

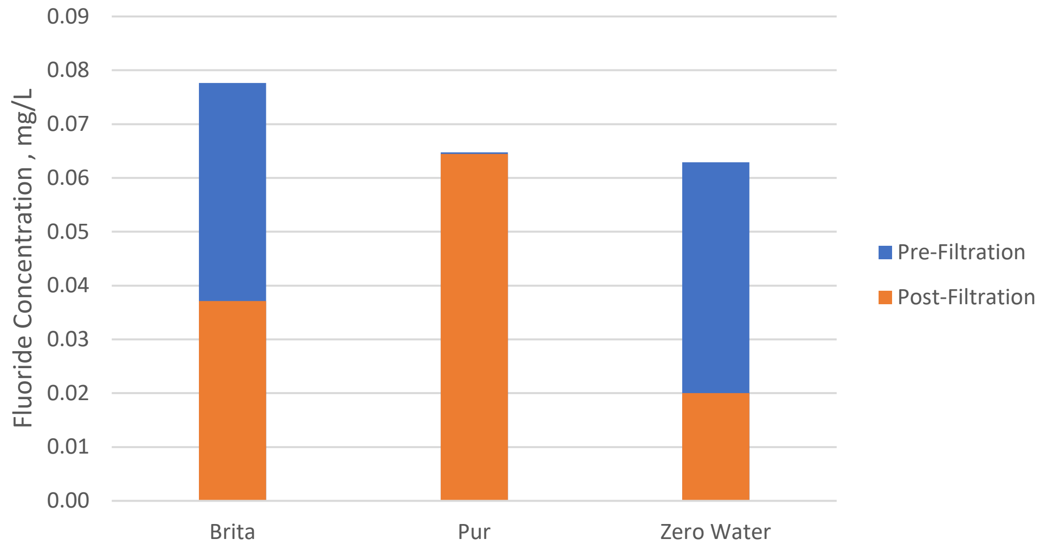
A total of 120 samples, including 6 control samples were tested to assess fluoride concentrations. The mean pre-filtration fluoride concentration was measured at 0.07 mg/L (SD = 0.01). Following the filtration process, samples using the Zero Water filter showed the lowest concentration at 0.02 mg/L (SD = 0.00), P<0.001. In contrast, the Pur filters showed no concentration change from baseline, P=0.57. Table 1 reports the pre and post-filtration fluoride concentrations by filter brand as well as the change from baseline.

A one-way ANOVA was performed to evaluate the impact filtration between brands. Analysis revealed that a significant difference in post-filtration fluoride concentration existed between samples based on the filter used, ($F(2,113) = 249.11$, $P < 0.001$). Tukey HSD post-hoc tests further showed significant differences between each of the three brands, all $P < 0.001$. However, due to initial differences in fluoride concentration, analysis of change in concentration from baseline failed to show a difference in filtration efficacy between the Brita and Zero Water filters as both lowered the concentration by 0.04 mg/L, P = 0.71. Figure 1 shows the pre and post-filtration concentrations by brand.

Table 1. Mean Fluoride Concentration by Brand

	Filter Brand	N	Mean (mg/L)	Std. Deviation
Pre-Filtration	Brita	38	0.08	0.01
	Pur	38	0.06	0.01
	Zero Water	38	0.06	0.02
Post-Filtration	Brita	38	0.04	0.01
	Pur	38	0.06	0.01
	Zero Water	38	0.02	0.00
Change form Baseline	Brita	38	0.04	0.01
	Pur	38	0.00	0.00
	Zero Water	38	0.04	0.02

Figure 1. Pre- and Post-Filtration Fluoride Concentrations by Filter Type



Discussion:

Prior studies are almost two decades old and only examine one-step filtration systems. Newer filtration systems utilize multi-step processes. The newest filtration systems employ activated carbon and ion exchange. Based on the results from this study it is possible for fluoride to be removed without a reverse osmosis system. The American Dental Association recommends community water fluoridation due to the prevention of demineralization and enhanced remineralization of enamel in contact with fluoride in saliva and plaque (1). The dental community and their patients need to be aware these reductions are possible with standard home filtration pitchers.

Zero Water filtration claims to remove 99% of fluoride. That claim was not verified by this study, however a significant amount of fluoride, 67%, was removed using the Zerowater and 50% with the Brita water filters. Pur does not comment on fluoride filtration and did not appear to impact fluoride levels. The Fluoride level recorded at Fort Bragg, NC was lower than the recommend level of 0.7mg/L. Fayetteville Public Works Commission supplies the water for Fort Bragg; They claim the fluoride level is 0.69mg/L, the mean level recorded was 0.07mg/L. The lowest level of Fluoride that the WS100 could read is 0.02 mg/L, considering this the level of fluoride remaining in the filtered water was not less than 0.02mg/L.

Conclusion:

Within the limitations of the study, it can be concluded that Zerowater and Brita remove a portion of fluoride from water. Due to the limitations of this study a percentage of fluoride removal cannot be accurately concluded. Future studies should consider multiple initial fluoride concentrations or a single standardized amount to correctly evaluate amount of fluoride removal. Additionally, a higher caliber fluoride ion meter should be considered.

Acknowledgements:

Special thanks to Mr. Thomas Beltran for assistance with the statistical analysis.
The views expressed herein are those of the author(s) and do not necessarily reflect the official policy of the Department of the
Army, Defense Health Agency, Department of Defense, or the US Government.

Military Significance:

Drinking fluoridated water has long shown to help maintain a healthy oral cavity by preventing future caries. The United States military is always looking for ways to improve and maintain Soldiers' oral health. When Soldiers use point-of-use filters, they need to know the impact this has on fluoride concentration. Military healthcare providers must be able to inform their patients about the effect common filtration systems have on water. By optimizing the fluoride concentration in drinking water, then Soldiers are set up for success in maintaining oral health.

Institutional Relevance:

Addresses Gap IV.C.2 (Instrument and device testing: Other materials and devices with significant implications in the military environment).

Citations/References:

1. ADA Division of Science of the ADA Council on Scientific Affairs. Tap water filters. *J Am Dent Assoc*. 2003;134(2):226-227. doi:10.14219/jada.archive.2003.0138

2. Brown MD, Aaron G. The effect of point-of-use water conditioning systems on community fluoridated water. *Pediatr Dent*. 1991;13(1):35-38.

3. Buzalaf MA, Levy FM, Rodrigues MH, Bastos JR. Effect of domestic water filters on water fluoride content and level of the public water supply in Bauru, Brazil. *J Dent Child (Chic)*. 2003;70(3):226-230.

4. Carey CM. Focus on fluorides: update on the use of fluoride for the prevention of dental caries. *J Evid Based Dent Pract*. 2014;14 Suppl:95-102. doi:10.1016/j.jebdp.2014.02.004

5. Centers for Disease Control and Prevention. Drinking water standards and regulations. Centers for Disease Control and Prevention. https://www.cdc.gov/healthywater/drinking/public/regulations.html. Published August 10, 2022. Accessed October 3, 2022.

6. Centers for Disease Control and Prevention (CDC). Ten great public health achievements--United States, 1900-1999. *MMWR Morb Mortal Wkly Rep*. 1999;48(12):241-243.

7. Clark DC. Appropriate uses of fluorides for children: guidelines from the Canadian Workshop on the Evaluation of Current Recommendations Concerning Fluorides. *CMAJ*. 1993;149(12):1787-1793.

8. Cutler D, Miller G. The role of public health improvements in health advances: the twentieth-century United States. *Demography*. 2005;42(1):1-22. doi:10.1353/dem.2005.0002

9. Eftekhar B, Skini M, Shamohammadi M, Ghaffaripour J, Nilchian F. The Effectiveness of Home Water Purification Systems on the Amount of Fluoride in Drinking Water. *J Dent (Shiraz)*. 2015;16(3 Suppl):278-281.

10 Environmental Protection Agency. Summary of the Safe Drinking Water Act. EPA. https://www.epa.gov/laws-regulations/summary-safe-drinking-water-act. Published 2018. Accessed October 3, 2022.

11. Gil-Bona A, Bidlack FB. Tooth Enamel and its Dynamic Protein Matrix. *Int J Mol Sci*. 2020;21(12):4458. Published 2020 Jun 23. doi:10.3390/ijms21124458

12. Health protection: Fluoridation and dental health. Public Health Rep. 1983 Sep-Oct;Suppl:94-7. PMID: 6414023; PMCID: PMC2047153

13. Hu Z, Morton LW, Mahler RL. Bottled water: United States consumers and their perceptions of water quality. *Int J Environ Res Public Health*. 2011;8(2):565-578. doi:10.3390/ijerph8020565

14. Jobson MD, Grimm SE 3rd, Banks K, Henley G. The effects of water filtration systems on fluoride: Washington, D.C. metropolitan area. *ASDC J Dent Child*. 2000;67(5):350-304.

15. Konno H, Yaegaki K, Tanaka T, et al. Neither hollow-fibre membrane filters nor activated-charcoal filters remove fluoride from fluoridated tap water. *J Can Dent Assoc*. 2008;74(5):443.

16. Loh KH, Yaacob H, Andan H, et al. A Study of The Effect of Home Water Filtration Systems On Fluoride Content of Drinking Water in Johor. Malaysian Dental Journal 2011; 33(2): 8-13.

17. Murphy HM, McBean EA, Farahbakhsh K. A critical evaluation of two point-of-use water treatment technologies: can they provide water that meets WHO drinking water guidelines?. *J Water Health*. 2010;8(4):611-630. doi:10.2166/wh.2010.156

18. Newbrun E. Current regulations and recommendations concerning water fluoridation, fluoride supplements, and topical fluoride agents. *J Dent Res*. 1992;71(5):1255-1265. doi:10.1177/00220345920710052001

19. Park S, Onufrak S, Patel A, Sharkey JR, Blanck HM. Perceptions of drinking water safety and their associations with plain water intake among US Hispanic adults. *J Water Health*. 2019;17(4):587-596. doi:10.2166/wh.2019.015

20. Prabhakar AR, Raju OS, Kurthukoti AJ, Vishwas TD. The effect of water purification systems on fluoride content of drinking water. *J Indian Soc Pedod Prev Dent*. 2008;26(1):6-11. doi:10.4103/0970-4388.40314

21. Rosinger AY, Herrick KA, Wutich AY, Yoder JS, Ogden CL. Disparities in plain, tap and bottled water consumption among US adults: National Health and Nutrition Examination Survey (NHANES) 2007-2014. *Public Health Nutr*. 2018;21(8):1455-1464. doi:10.1017/S1368980017004050

22. Sobsey MD, Bartram S. Water quality and health in the new millennium: the role of the World Health Organization Guidelines for Drinking-Water Quality. *Forum Nutr*. 2003;56:396-405.

23. Song Y, Kim J. Community Water Fluoridation: Caveats to Implement Justice in Public Oral Health. *Int J Environ Res Public Health*. 2021;18(5):2372. Published 2021 Mar 1. doi:10.3390/ijerph18052372

24. U.S. Department of Health and Human Services Federal Panel on Community Water Fluoridation. U.S. Public Health Service Recommendation for Fluoride Concentration in Drinking Water for the Prevention of Dental Caries. *Public Health Rep*. 2015;130(4):318-331. doi:10.1177/003335491513000408

25. Brita. Better Water . Brita. http://www.brita.com/why -brita/better-water/. Published 2022. Accessed October 3, 2022.

26. PUR. Pur Plus . PUR.com homepage. http://www.pur.com/shop/pitchers/pur-plus-11-cup-pitcher. Published 2022. Accessed October 3, 2022.

27. Zero Water. Water Filter Performance & Comparison Results. ZeroWater. https://zerowater.com/pages/results. Published 2022. Accessed October 3, 2022.