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LITERATURE REVIEW

The Correlation between Fluoride Content in Bottled Water with Dental Caries Status: A Literature Review

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Fluorides; Dental Caries; Tooth Remineralization.

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ABSTRACT
Background: Caries is a dental infectious disease that causes demineralization of tooth structure. Based on Basic Health Research in 2018, the prevalence of tooth decay, cavities, and toothache in Indonesia reached 45.3%. It states that dental caries proportion is one of the biggest problems in Indonesia. Tooth remineralization requires sufficient fluoride. The need for bottled water is growing very rapidly around the world because consumers believe in practicality and good quality. Previous research suggested that further research on it is needed. **Objective:** To describe the correlation between fluoride content in bottled water with dental caries status. **Methods:** This is a type of Systematic Literature Review study using secondary data in the form of articles published on the PubMed database, Science Direct, Google Scholar, Ebsco, and Proquest. **Results:** A Systematic review of 16 articles showed that the majority of the fluoride content in bottled drinking water was still below recommendations. Optimal fluoride content in bottled water is correlated to low dental caries status. **Conclusion:** There is a correlation between fluoride content in bottled water with dental caries status.

I. INTRODUCTION

Caries is a dental infection caused by the interaction between microorganisms on the plaque, cariogenic foods especially carbohydrates, tooth surface, and time which result in demineralization of tooth structure (1). Caries is a major problem in the world and Indonesia. The Global Border of Disease Study in 2016 stated that caries might be a disease that is experienced by almost everyone in the half of world's population, or about 3.58 billion people. The National Report of *RISKESDAS* (Basic Health Research) in 2018 stated that the proportion of tooth problems such as tooth decay, cavities, and toothache was the highest at 45.3% (2).

The highest prevalence of caries was found in the 5 – 9 years old group, 45 – 54 years old group, and 35 – 44 years old group in Central Java were respectively 53.1%, 49.91%, and 47.78%. The prevalence of these three age groups was on the big three of nine age groups (3). The process of caries is not only the demineralization but also the remineralization process which replaces the lost tooth organic matrix. This process requires the significant role of flour in the oral cavity along with the saliva which binds calcium and phosphate ions to form fluorapatite which is a tooth strengthening acid-insoluble mineral (4),(5).

The biggest systemic fluoride source is the daily consumed drinking water (6). Bottled water is a variant of drinking water of which demand quickly increased around the world as the consumers highly trust the practicality and the good quality of the water (7). The need for bottled water from 2009 to 2014 highly improved (8). Fluor is one of the chemical parameters which is needed to be measured as it is included in the requirement of qualified drinking water (9), (10). It has to be fulfilled to avoid toxicity and to ensure that the fluoride in the water is beneficial for the health. U.S. Department of Health and Human Services recommends the content of fluoride in the drinking water at 0.7 mg/L as it can avoid caries, lower the risk of dental fluorosis and avoid other health problems related to fluoride toxicity (11).

Research by Abouleish mentioned that the low fluoride content among 0.08 – 0.10 mg/L in

bottled water correlated to dental caries (7). The newest research by Tanumihardja and Rehatta found the contribution of optimum fluoride content in the consumed drinking water to the low caries status with the average DMF-T index score at 1.95 (12). The limited research subject on the research led the researcher to recommend further research about the fluoride content in bottled water and its correlation with the dental caries status.

This research aimed to elaborate on the correlation between the content of fluoride in bottled water with the dental caries status, and also find out the optimum fluoride content which is beneficial to prevent dental caries based on the policy recommendation.

2. MATERIALS AND METHODS

It was a systematic literature review that used secondary data from the previous research of the researcher. The inclusion criteria of the research were the observational research articles published from 2012 to 2021 which used bottled water as the sample. The exclusion criteria were the article published before 2012, the text couldn't be fully accessed, and didn't focus on the research problem.

The research articles were browsed from PubMed Google Scholar, Science Direct, Ebsco, and ProQuest databases by using keyword combinations to identify the relevant article. The keyword combinations were in English, such as ("fluoride" or "fluorides" or "fluoride concentration" or "fluoride drinking water" and "bottled water" or "bottled drinking water" or "water" and "caries" or "dental caries") and in Bahasa Indonesia with the keyword ("fluorida" and "*air minum kemasan*" and "*karies*" or "*karies gigi*" and "*masyarakat*" and "Indonesia").

A large amount of found articles was minimalized by using the filter in every database such as category, subject type, and publication title. On Science Direct database with the "research" and "review article" category, also Medicine & Dentistry and Environmental Science subject type. On Ebsco database, the category used was "academic journals" with "dental caries", "drinking water quality", "oral hygiene", "cavity prevention", "fluorides", "cross-sectional method", "prevention", "socioeconomic factors", "children's health", "children", "beverages", "dental caries risk factor", "health status indicators", "public health", "dental public health", "water supply", "drinking water", "oral health", "world health organization", "dentistry", "health behavior", and "nutrition & oral health" as the subject type. On the ProQuest database, the publication title used in the screening were BMC Oral Health, International Journal of Environmental Research and Public Health, Indian Journal of Dental Research, Journal of the Indian Society of Pedodontics and Preventive Dentistry, Journal of Conservative Dentistry, International Journal of Dentistry, Fluoride, BMC Public Health, Journal of International Society of Preventive & Community Dentistry, and International Journal of Oral Science.

The articles found from the systematic review of the PRISMA flow diagram (Chart 1) were identification, screening, and a comprehensive feasibility study.

3. RESULTS

The finding in the article research from five databases were 1,871 from *PubMed*, 34,748 from *Science Direct*, 15 from *Google Scholar*, 564 from *Ebsco*, and 3,317 from *ProQuest* with a total of 40,515 research articles. After discarding some articles with the same title, it was found that the total number of articles was 40,511. The screening of the title and abstract based on the inclusion criteria found 36 articles. After that, 40,475 articles were discarded as they were not suitable for the inclusion criteria. The total articles that passed the full-text feasibility test and critical appraisal were 16 articles which would also be synthesized, meanwhile, the rest 20 articles were discarded for the discrepancy with the inclusion criteria.

The review showed that there were 16 Indonesian and International articles with cross-sectional and cohort research designs. Based on the study recommendation, 3 articles did not measure the fluoride content but were able to explain that the fluoride content in the bottled water is correlated to the dental caries status. Meanwhile, there was one article that showed the presupposition that fluoride in bottled water contributed to the average score of low DMF-T index.

Most of the 12 articles only measured fluoride content in the bottled water in the reference to policy recommendations (Table 1) without measuring and correlating with the dental caries status. The review result of the 12 articles found that four research has the largest sample from some continents such as Asia, Africa, South America, and Europe so it was found that the fluoride content in the bottled water was mostly under the optimum policy recommendation to prevent dental caries. Based on the article synthesis, four articles stated that the Fluor content

in bottled water is correlated to the dental caries status. However, 12 articles stated that fluoride content in bottled water was mostly under the optimum national or international policy recommendation. The synthesis of the 16 articles is available in Table 2.

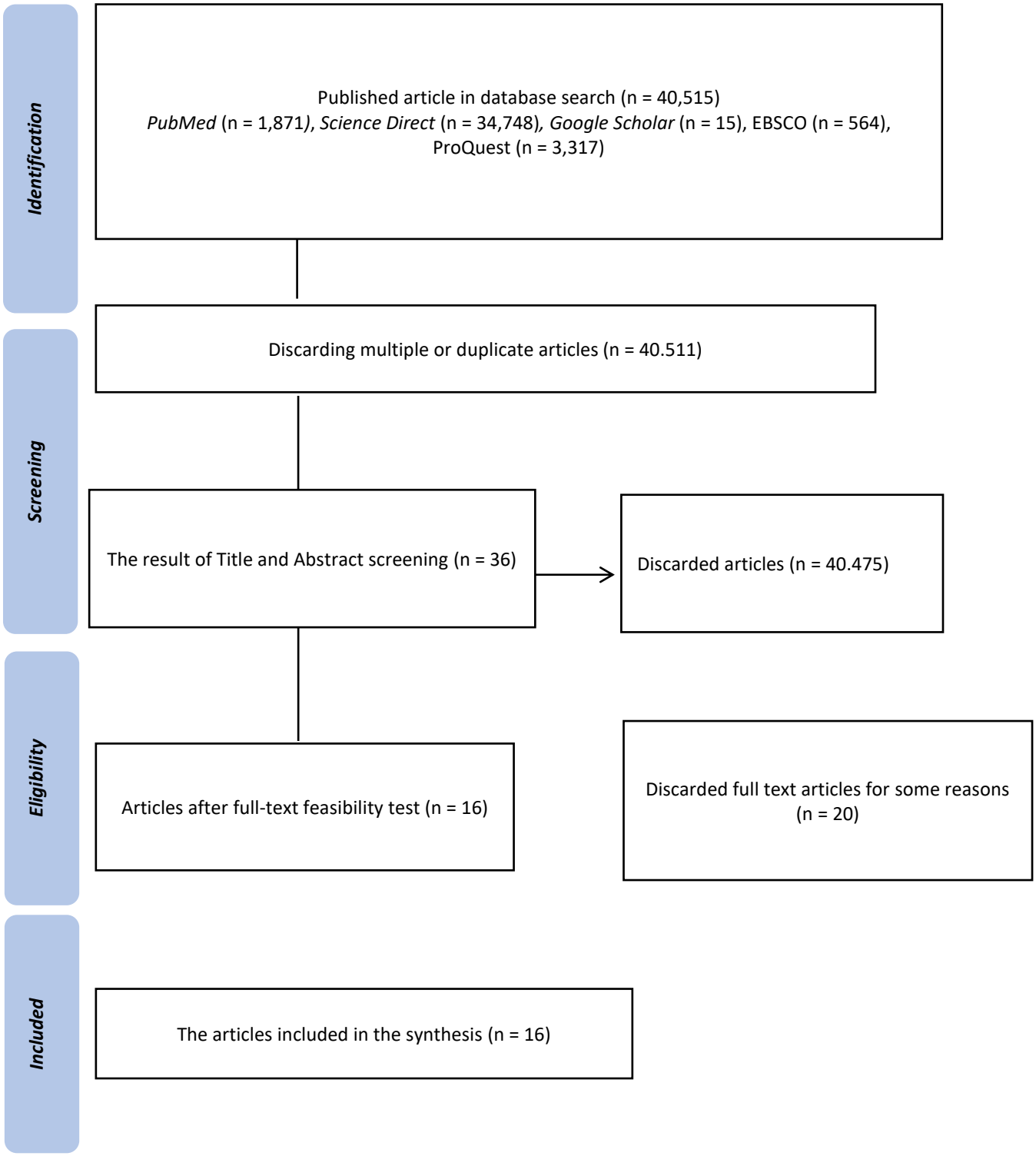

Chart 1. PRISMA Diagram of Systematic Review Stages of All Databases (13)

Table 1. Optimum Fluoride Content Recommendation

Standard/Policy Recommendation	Country Organization	Optimum Fluoride Content	Researcher
	International		
AAPD	USA	0.7 mg/L / ppm F	Reyes *et al*. 2019
ADA	USA	0.7 – 1.2 mg/L / ppm F	Tanumihardja & Rehatta. 2017
HHS	USA	0.7 mg/L / ppm F	Maraver *et al*. 2014
HHS & EPA 2011	USA	0.7 mg/L / ppm F	Doumit, Aad, & Machmouchi. 2019
U.S. FDA/CFR	USA	1.4 – 2.4 mg/L / ppm F (79.3 – 90.5 °F)	Abouleish. 2016
			Bengharez *et al*. 2011
WHO 1994	Geneva	0.5 – 1.0 mg/L / ppm F	Ćosić *et al*. 2019
WHO 2006	Geneva	0.6 – 0.8 mg/L / ppm F (26.3 °C – 32.6 °C)	Al-Mulla, Anthonappa, & King. 2016
WHO 2011	Geneva	0.7 – 1.5 mg/L / ppm F	Ani *et al*. 2020
	Regional		
GGC	Middle East	0.6 – 1.7 mg/L / ppm F	Abouleish. 2016
Iranian National Standard	Iran	0.7 – 1.2 mg/L / ppm F	Fard *et al*. 2015
Ministry of Health of Chile	Chili	0.6 – 1.0 mg/L / ppm F	Fernández, Giacaman, & Cury. 2014
Ministry of Health of Spain	Spain	0.6 – 0.8 mg/L / ppm F	Silva *et al*. 2020

Tabel 2. Study Characteristics of the 16 Synthesized Articles

Researcher, Year, Research Location, Research Design	Fluor content in bottled water (mg/L)	Dental Caries Status	Research finding	The correlation between Fluoride content in bottled water with Dental Caries Status
Marshall *et al*. 2021. Amerika Serikat, *Cohort*	-	DFSAR dental examination	Water lowers the DFSAR score by 29%	There is a correlation between water / SFB consumption and brushing teeth with the experience of dental caries in 17 years old participants
Fernández, Giacaman, & Cury. 2014. Brasil, *Cross-sectional*	<0.02 – 1.24	-	Fluor content under the recommendation	-
Reyes *et al*. 2019. Spanyol, *Cross-sectional*	0.05 – 0.95	-	The average Fluor content under the recommendation	-
Maraver *et al*. 2014. Spanyol, *Cross-sectional*	<0.03 – <1.2	-.	The Mean Fluor content under the recommendation	-
Abouleish. 2016. The United Arab Emirates, *Cross-sectional*	Mean 0.14 and 0.58	-	The Mean Fluor content under the recommendation	-

Researcher, Year, Research Location, Research Design	Fluor content in bottled water (mg/L)	Dental Caries Status	Research finding	The correlation between Fluoride content in bottled water with Dental Caries Status
Al-Mulla, Anthonappa, & King. 2016. HongKong, Qatar, *Cross-sectional*	<0.6	-	The Mean Fluor content under the recommendation	-
Ani *et al*. 2020. Nigeria, *Cross-sectional*	0.013 – 0.017	-	Fluor content under the recommendation	-
Doumit, Aad, & Machmouchi. 2019. Lebanon, *Cross-sectional*	0.02 – 0.23	-	Fluor content under the recommendation	-
Almulla *et al*. 2016. Qatar, *Cross-sectional*	0.06 – 3.0	-	The Mean Fluor content is under the recommendation the 28.1% the content is >1.2 mg/L	-
Bengharez *et al*. 2012. Aljazair, *Cross-sectional*	0.19 – 1.07	-	The Mean Fluor content is under the recommendation	-
Suratri, Jovina, & Notohartojo. 2018. Indonesia, *Cross-sectional*	-	DMF-T index examination	All drinking water sources except refilled drinking water contribute to dental caries	There is a correlation between refill drinking water consumption with dental caries
Tanumihardja, & Rehatta. 2017. Indonesia, *Cross-sectional*	Mean 0.88	Pemeriksaan indeks DMF-T: 1,95	The mean of optimum Fluor content contributes to the low DMF-T index	There is a conception about optimum Fluor content with low dental caries status.
Fard *et al*. 2015. Iran, *Cross-sectional*	0.04 – 0.32	-	Fluor content is under the recommendation	-
Ćosić *et al*. 2019. Serbia, *Cross-sectional*	0.077 – 0.185. 0.089-0625 mg/day Fluor intake	-	There is no significant difference in daily Fluor intake from drinking water and toothpaste (14).	-
Silva *et al*. 2020. Spanyol, *Cross-sectional*	<0.6	-	Fluor content is under the recommendation	-
Peltzer, *et al*. 2014. Thailand, *Cohort*	-	The deft and defs index examination	The increase of caries status of 24 – 36 months participants (52.9%)	There is a correlation between drinking water consumption behavior with the increase in dental caries

4. DISCUSSION

Caries is a multifactorial disease that could be influenced by the social behavior risk factors such as environmental factors, socio-culture factors, oral and dental health care systems, and behavior factors. The measurement of dental caries depends on the index (15). The severity of dental caries usually increases as the increase of one's ages because of the prolonged exposure to the caries risk factors (12),(16).

Caries do not only attack permanent teeth, but also the primary teeth. It is because primary teeth have a different structure than permanent teeth. Peltzer et al., (2014) (17) stated that caries is increased in children aged 24 months (34.2%) and 36 months (68.5%). Aside from the morphology factors of primary teeth, the level of a mother's

knowledge of children's oral hygiene and the habit to leave bottles in their sleeping baby's mouth can cause dental caries.

Generally, females tend to experience more dental caries compared to males, related to their diet (16). This theory is in contrast with the research from Tanumihardja and Rehatta, (2017) (12) that males got a higher score on it as females tend to give more attention to their appearance, while males have a smoking habit. Cohort research by Marshal et al., (2021) (18) found that the mean DFS score on 17 years old participants was 1. It meant that 1 tooth had caries on it which might be caused by the drinking water consumed since they were born till they were 17 years old.

Systematically, the most prominent source of Fluor is from the drinking water, aside from the Fluor-contained diet and Fluor supplement. The topical effect would appear after the direct contact with the teeth, such as fluoride toothpaste, fluoride mouthwash, also varnish, gels, and sealant (19).

Fluor ion is often called nature's cavity fighter which can prevent tooth decay and even possess a healing effect by making use of bone structure mineralization (20),(21). Fluoride has three general mechanisms in preventing dental caries which are: (1) improve remineralization by binding calcium ion and phosphate in the email matrix with Fluor ion to form more caries-resistant fluorapatite, (2) Inhibit demineralization, (3) Decrease the potency of plaque bacteria metabolism (22).

The concentration of Fluor content is significantly correlated to the source of drinking water consumed every day. This theory is proved by Suratri et el., (2018) (16) that dental caries cases were significantly correlated to the source of the drinking water, as mentioned that most of the sources of drinking water contributed to dental caries, except the refilled drinking water and tap water.

Research is done by Tanumihardja and Rehatta, (2017) (12) described optimum Fluor content with low dental caries status. Besides the sufficient exposure to Fluor, there were also some other factors related to the dental caries prevalence such as brushing teeth using fluoride toothpaste twice a day, visiting the dentist regularly, and consuming healthy foods including vegetables, fruit, and milk as the source of Fluor.

Peltzer et al., (2014) (17) analyzed the correlation of some behavioral factors related to the increase of children's caries prevalence, such as the source of drinking water from soil water, rainwater, and bottled water as they have different Fluor effects in preventing dental caries. The research stated that the daily consumption of soil water and rainwater as the source of drinking water correlated to the dental caries status in children.

The consumption of sweet beverages or Sugar-Sweetened Beverages (SSB) is correlated to the increase in dental caries risk. Research by Marshall et al., (2021) (18) stated that there is a correlation between Sugar-Free Beverage fluoride (SFBf) consumption with the lower DFSAR score in 17 years old respondents. The higher SBFf consumption level with the more regular tooth brushing habit are the protective factors of dental caries.

Insufficient or excessive Fluor intake could stimulate caries and fluorosis so it is important to set a standard or policy recommendation. The objective of setting the standard could help dentists who are directly involved in primary dental care in observing the right amount of fluoride attached to the label of bottled water and avoiding the consumption of formula milk which is dissolved in water with a high level of Fluor content (23).

Fluor content in bottled water doesn't give wither good or bad consequences in our health, as it is saved to be consumed every day, but cannot give more contribution in preventing dental caries due to the under policy recommendation Fluor content. The theory is supported by some research with the largest sample that the result of Fluor content measurement in bottled water mostly reported that it is still under the optimum score based on the policy recommendation (23),(24),(25),(26).

Excessive Fluor contributes to health problems such as tooth and bone fluorosis, especially from the tooth formation period to the 8 following years(27). There is a significant correlation between Fluor content in bottled water produced by some countries, such as the bottled water produced by Saudi Arabia which contains higher Fluor than those produced in Qatar, UAE, and Lebanon. It is because some region doesn’t have river and lake, and only uses soil water and desalinated seawater as the source of drinking water (28). Based on research by Bengharez et al., (2012) (29) almost all bottled water contains low Fluor content. However, it is beneficial for the population that lives in South Aljazeera as the fluorosis endemic region.

Bottled water has a good quality, is natural, and has no disturbing taste and smell (30). Fluor contained in bottled water could be affected by

some factors such as the source of water, time of water collection, and fluoridation technique. There is a correlation between Fluor content in bottled water with the type of water source (mineral, demineralize, natural mineral water) (7). However, it is in contrast with the research done by Al-Mulla et al., (2016) (23). Research by Abouleish, (2016) and Al-Mulla et al., (2016) also showed that there is no correlation between Fluor content in bottled water with the local or imported source of drinking water.

Most drinking waters have included the Fluor content in their package label. However, some brands don't constantly report it (23),(26). It could bring disadvantages for the dentists as they will find difficulty in planning Fluor therapy. In addition to this, the information about fluoride content is also needed by the consumers to find suitable drinking water for their daily consumption.

The regulation set by the UN and Spain states that if a product contains >1 mg/L and >1.5 mg/L Fluor should include the statement “fluoridated or containing fluoride or containing >1.5 mg/L Fluor, not suitable for regular consumption by infants and children under 7” on the label (27).

5. CONCLUSIONS

There is a correlation between fluoride content in bottled water with dental caries status. However, most bottled water contains an insufficient level of Fluor content which is under the national or international policy recommendation.

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