IJETST- Vol.||05||Issue||06||Pages 6637-6645||June||ISSN 2348-9480 2018

Open access Journal International Journal of Emerging Trends in Science and Technology

IC Value: 76.89 (Index Copernicus) Impact Factor: 4.849 DOI: https://dx.doi.org/10.18535/ijetst/v5i6.03

Original Research Article

Relationship of Drinking Water to Dental Calculus in Saudi Arabia: Riyadh in Comparison to Eastern Province

Authors

Rahaf Safadi[1,2], Riham Al-Safadi[1], Reef Al-Safadi[1], Zahra Al-Saigh[2], Maram Al-Otaibi[2], Hassan Al-Farraj[2], Fatimah Al-Otaibi[2], Amal Al-Abdulwahab[2] Yasmeen Al-Bagshi[2]

[1]Department of Preventive Dentistry, College of Dentistry, Riyadh Elm University, Riyadh, Kingdom of Saudi Arabia

[2]University Dental Hospital, College of Dentistry, Riyadh Elm University, Riyadh, Kingdom of Saudi Arabia

Corresponding Author

Rahaf Safadi

Department of Preventive Dentistry, University Dental Hospital, College of Dentistry, Riyadh Elm University, P.O. Box (84891) Riyadh (11681) Kingdom of Saudi Arabia

Email: *dr.rahaf@riyadh.edu.sa*, Telephone: (+966) 920000842, Fax: (+966) 920000843

Abstract

Aim: *The aim of this study was to detect the influence of drinking water on the occurrence and severity of dental calculus in Saudi Arabia through comparing the amount of dental calculus on teeth surfaces and the type of drinking water in addition to other contributing factors between two provinces in the Kingdom of Saudi Arabia which were Riyadh and Eastern Province and to define the mineral elements in drinking water causing such effect.*

Materials and Methods: *304 patients aged ≥18 years who live in the Kingdom of Saudi Arabia (Riyadh and Eastern Province) were randomly selected and equally divided into two groups: Riyadh group and Eastern Province group. The study was carried out in the period April through June 2018. Each patient was clinically examined using Oral Calculus Index (OCI) (Greene and Vermillion 1964)[1] and Saliva pH Test (pH indicator papers full range). Also, each patient answered a questionnaire about: oral hygiene habits, the last visit for dental scaling, the type of drinking water, the amount of daily water consumption, and tobacco smoking. Laboratory analysis of drinking water samples for (Ca) and (PO_4) mg/L ppm was performed. The data obtained were documented in a patient examination form then statistically analyzed using Chi-Square Test and Multinomial Logistic Regression.*

Results: *There was a statistically significant relationship between the type of drinking water and calculus $p<0.05$. Also, there was a statistically significant relationship between provinces and calculus $p<0.05$. There was a significant difference between the two provinces $p<0.05$ in the type of drinking water and saliva pH. However, there was an insignificant difference between the two provinces $p>0.05$in oral hygiene habits (brushing, flossing, mouthwash), the last visit for dental scaling, the amount of daily water consumption, and tobacco smoking. Eastern Province that depended more on water from trucks than Riyadh had higher alkaline saliva pH and higher calculus risk than Riyadh.*

Conclusion: *The results of this study indicate that drinking water influences the occurrence and severity of dental calculus. It's important to comply with the international standards of (Ca), (PO_4), and (Mg) concentration mg/L ppm in drinking water. Periodic analysis is advised.*

Keywords: *Calculus, Type of Water, Trucks, Bottles, Tap Water, Ca, PO_4.*

Introduction

Drinking water and the oral cavity

Two of the acquired exterior factors that can change the pH level and concentration of ions in the environment surrounding teeth are food and liquids consumed by humans including drinking water. Changes in the content and physiochemical properties of drinking water affect the process of mineralization in the oral cavity in two ways. Firstly, through their systemic impact on the balance of the mineral content such as calcium, magnesium, and phosphate thus the concentration of these components secreted with saliva. Secondly, through their local impact on teeth when drinking water and consuming food prepared on water base.[2]

In 1937, Mills found (among 75 cities in the USA) a direct relationship between the mineral content of drinking water especially water hardness (calcium and magnesium content) and its effect on the resistance and susceptibility of teeth to demineralization. In his study, he suggested that caries diminished as drinking water hardness increased.[2,3]

Dental calculus composition and formation

Dental calculus is primarily composed of inorganic and organic components. Minerals form the inorganic part of supragingival and subgingival calculus and constitute 37% and 58% by volume, respectively.[4,5] The inorganic (mineral) part of dental calculus consists of calcium phosphate crystals: octacalcium phosphate, hydroxyapatite, whitlockite, and brushite. The driving force for dental plaque mineralization thus dental calculus formation is supersaturation of saliva, plaque fluid in particular, with calcium phosphate salts.[4]Moreover, literature lists a high-calcium and high-phosphorus diet as a possible contributor to dental calculus formation in addition to local concentrations of other minerals such as magnesium, potassium, iron, and silicon that may also be important in the regulation of dental calculus formation.[6,7]

Materials and Methods

Ethical approval

The study was registered with the research center of Riyadh Elm University (FRP/2018/160) and received ethical approval from the institutional review board of the same institution (RC/IRB/2018/968).

Selection of the content for analysis and statistical analysis

304 patients aged ≥18 years who live in the Kingdom of Saudi Arabia (Riyadh and Eastern Province) were randomly selected and equally divided into two groups: Riyadh group and Eastern Province group for the purpose of achieving comparison. The study was conducted in the period April through June 2018. After taking the patient consent on an informed consent statement form for clinical studies, each patient was clinically examined using Oral Calculus Index (OCI) (Greene and Vermillion 1964)[1]and Saliva pH Test(pH indicator papers full range) in order to detect the saliva pH (acidic, neutral, alkaline). In addition, each patient answered a questionnaire about: oral hygiene habits(tooth brushing, dental flossing, mouthwash), the last visit for dental scaling, the type of drinking water (water from trucks, bottles, tap water), the amount of daily drinking water consumption (glass of water), and tobacco smoking. Laboratory analysis of four drinking water samples for calcium (Ca) and phosphate (PO_4) mg/L ppm was done. All the water samples were kept in sterile containers with tight plastic caps. They were delivered to the lab upon collection from their natural sources, and the bottled water sample was valid for a one year from its production date as indicated on its container. The water samples were as the following:

Sample1. Bottled water from a Saudi water factory. Riyadh, KSA.

Sample 2. Tap water. Al-Jubail, Eastern Province, KSA.

Sample 3. Water from a well with a desalination home device. Al-Hofuf, Eastern Province, KSA.

Sample 4. Water from a truck refilled in a water refill station. Riyadh, KSA.

The analytical laboratory testing techniques were:

I-Color mating spectrophotometer for detecting (PO_4) mg/L ppm

II-(ICP) Inductively coupled plasma atomic emission spectrometer for detecting (Ca) mg/L ppm

The data obtained were documented in a patient examination form then statistically analyzed using Chi-Square Test to test the association between categorical variables and Multinomial Logistic Regression to evaluate the relationship between nominal dependent variable (calculus) and risk factors (provinces and the type of drinking water). Odd Ratio was calculated to compare the Odd Ratio of (heavy/moderate) calculus versus no calculus and the Odd Ratio of slight calculus versus no calculus for each of the aforementioned risk factors. All statistical analyses were performed using the IBM SPSS Statistics version 20 data processing software. The significance level was set at $p < 0.05$.

Results

Relationship between nominal dependent variable (calculus) and risk factors (provinces and the type of drinking water)

Multinomial Logistic Regression model was significant p=0.000<0.05 (Chi-Square=24.395, df =4) and valid with classification accuracy=51.6% which was greater than the proportional by chance accuracy criteria 51.06% (1.25 x 0.408518) (Table 1). Also, it was a well-fitting model according to the Goodness-of-Fit Test p = 0.695 > 0.05.

The intercept of the dependent variable (heavy/moderate) calculus and the risk factors (provinces and the type of drinking water) was statistically significant p=0.000<0.05, intercept =1.576. Also, the intercept of the dependent variable slight calculus and the risk factors (provinces and the type of drinking water) was statistically significant p=0.000< 0.05, intercept = 1.786 (Table2).

Table 1: Model Fitting Information

Model	Likelihood Ratio Tests		
	Chi-Square	df	Sig.
Final	24.395	4	.000

The type of drinking water and dental calculus

Chi-Square Test showed that there was a statistically significant relationship between the type of drinking water (trucks/tap water, bottles) and calculus severity (no calculus, slight calculus, and heavy/moderate calculus) p =0.004<0.05 (Chart 1).

Multinomial Logistic Regression showed that the type of drinking water (trucks/tap water, bottles) played a statistically significant role in differentiating patients who had (heavy/moderate) calculus from patients with no calculus p=0.017<0.05. Patients who used to drink water from (trucks/tap water) were three times more likely -higher risk- to have (heavy/moderate) calculus than patients who used to get their drinking water from bottles Odd Ratio =3.079 (Lower Bound=1.220, Upper Bound=7.773) at a confidence level 95%. However, Multinomial Logistic Regression showed that the type of drinking water(trucks/tap water, bottles) didn't differentiate patients who had slight calculus from patients with no calculus p =0.102 >0.05 (Table 2).

Table 2: Parameter Estimates of nominal dependent variable (calculus) and risk factors (provinces and the type of drinking water)

Calculus Index[a]		B	Sig. p-value	Exp (B) Odd Ratio	95% Confidence Interval for Odd Ratio	
					Lower Bound	Upper Bound
Heavy / Moderate	Intercept	1.576	.000			
	Riyadh	-1.423	.001	.241	.102	.569
	Eastern Province	0[b]	.	.	.	.
	Trucks/Tap Water	1.125	.017	3.079	1.220	7.773
	Bottles	0[b]	.	.	.	.
Slight	Intercept	1.786	.000			
	Riyadh	-.882	.037	.414	.181	.949
	Eastern Province	0[b]	.	.	.	.
	Trucks/Tap Water	.754	.102	2.124	.861	5.243
	Bottles	0[b]	.	.	.	.

a. The reference category is: No Calculus
b. This parameter is set to zero because it is redundant

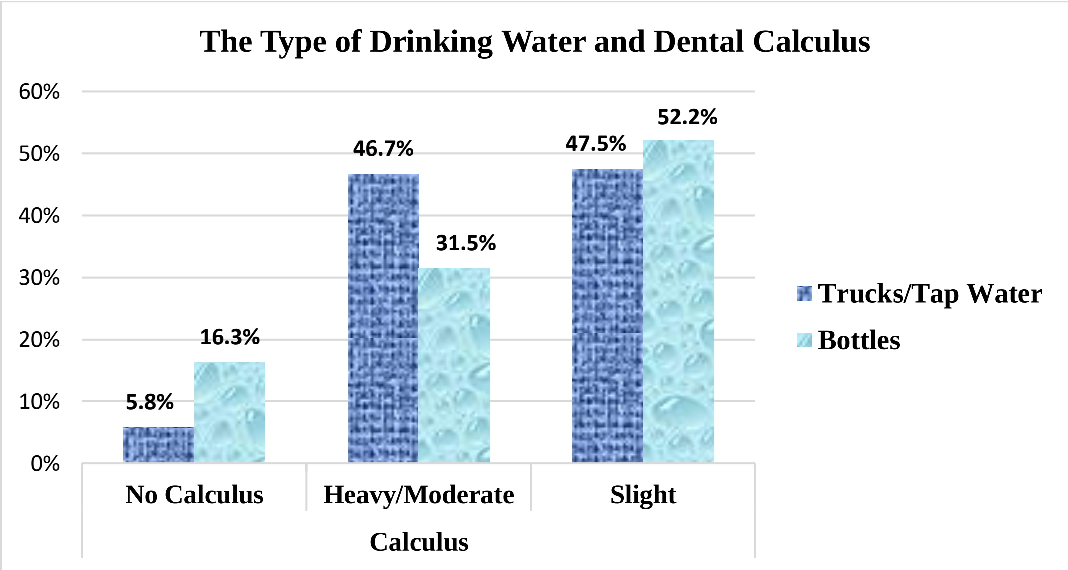

Chart 1: The type of drinking water and dental calculus

Provinces and dental calculus

Chi-Square Test showed that there was a statistically significant relationship between provinces (Riyadh, Eastern Province) and calculus severity (no calculus, slight calculus, and heavy/ moderate calculus) p =0.000 <0.05 (Chart 2). Multinomial Logistic Regression showed that provinces (Riyadh, Eastern Province) played a statistically significant role in differentiating patients who had (heavy/moderate) calculus from patients with no calculus p =0.001<0.05. Patients from Riyadh were 75.9% less likely -lower risk- to have (heavy/moderate) calculus than patients from Eastern Province Odd Ratio=0.241(Lower Bound=0.102, Upper Bound=0.569) at a confidence level 95%. Also, Multinomial Logistic Regression showed that provinces (Riyadh, Eastern Province) played a statistically significant role in differentiating patients who had slight calculus from patients with no calculus p =0.037<0.05. Patients from Riyadh were 58.6% less likely -lower risk- to have slight calculus than patients from Eastern Province Odd Ratio=0.414 (Lower Bound=0.181, Upper Bound=0.949) at a confidence level 95% (Table 2).

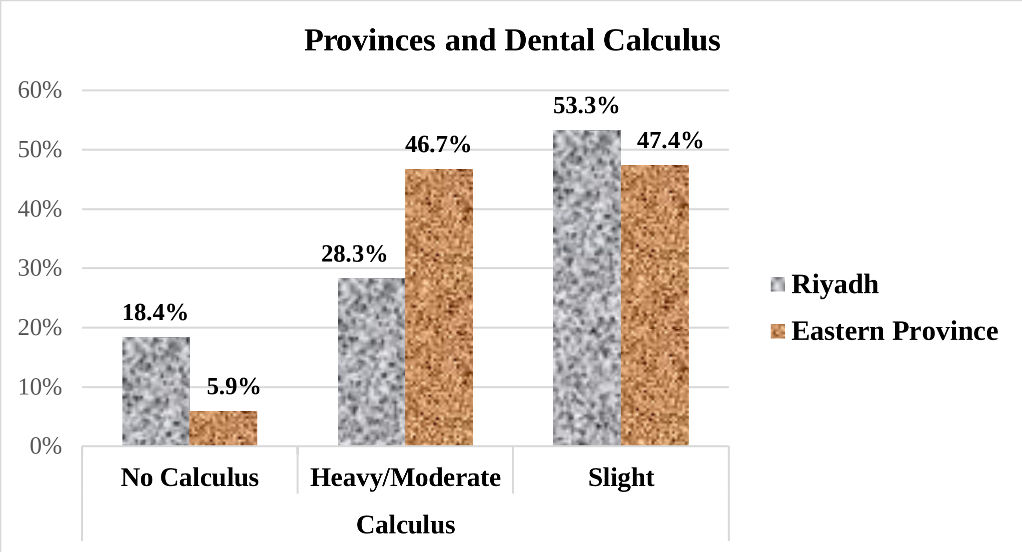

Chart 2: Provinces and dental calculus

Provinces and the type of drinking water

Chi-Square Test showed that there was a significant difference between Riyadh and Eastern Province in the type of drinking water (trucks, bottles, and tap water) p =0.000 <0.05. The type of drinking water in Eastern province was water from trucks (34.2%), bottles (48.7%), and tap water (17.1%). However, the type of drinking water in Riyadh was water from trucks (7.9%), bottles (72.4%), and tap water (19.7%) (Chart 3).

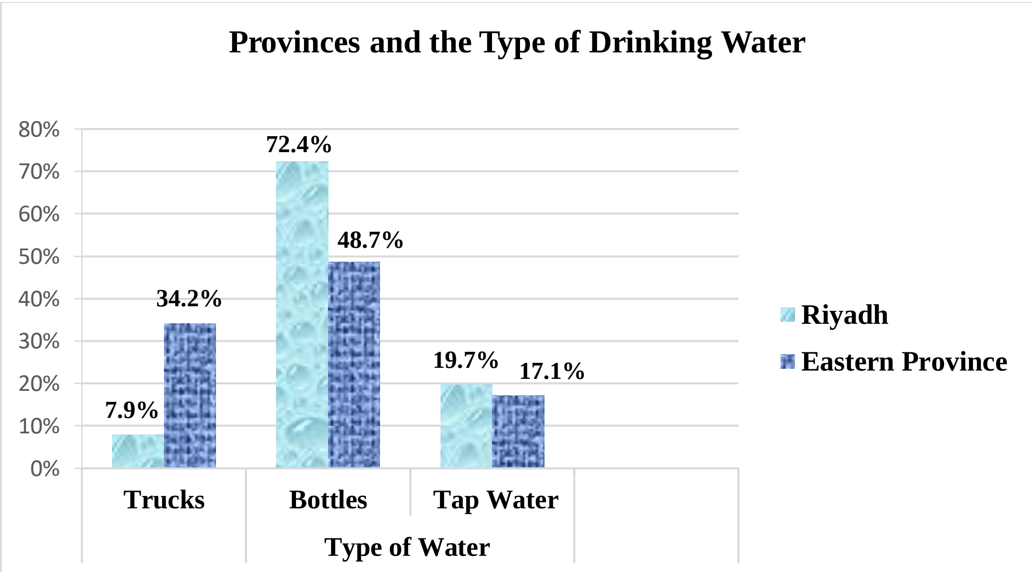

Chart 3: Provinces and the type of drinking water

Saliva pH

Chi-Square Test showed that there was a significant difference between Riyadh and Eastern Province in saliva pH p =0.022 < 0.05. The saliva pH in Eastern Province was alkaline (34.9%), neutral (57.2%), and acidic (7.9%). However, the saliva pH in Riyadh was alkaline (28.3%), neutral (53.3%), and acidic (18.4%) (Chart 4).

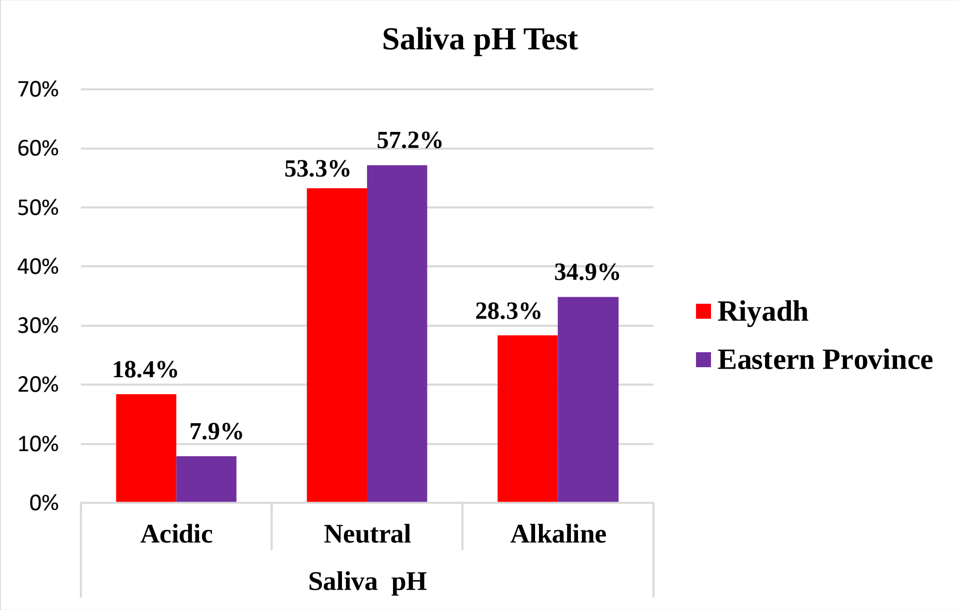

Chart 4: Saliva pH Test

Oral hygiene habits and dental scaling

Chi-Square Test showed that there was an insignificant difference between Riyadh and Eastern Province in oral hygiene habits p >0.05: tooth brushing p =0.492 >0.05, dental flossing p =0.516 >0.05, and mouthwash p =0.278 >0.05. Also, Chi-Square Test showed that there was an insignificant difference between Riyadh and Eastern Province in the last visit for dental scaling p =0.118 >0.05 (Table 3).

Daily water consumption

Chi-Square Test showed that there was an insignificant difference between Riyadh and Eastern Province in the amount of daily drinking water consumption p=0.454 >0.05 (Table 3).

Tobacco smoking

Chi-Square Test showed that there was an insignificant difference between Riyadh and Eastern Province in tobacco smoking p =0.883 >0.05 (Table 3).

Table 3: Statistical comparison between Riyadh and Eastern Province

Questions included in the questionnaire	**Significant or insignificant difference between Riyadh and Eastern Province p-value**
How many times do you brush your teeth per day? ○I never brush ○ one time ○ two times ○ more than two times	0.492>0.05 insignificant difference
How many times do you use dental floss per week? ○ I never floss ○ once a week ○ twice a week ○ more than twice a week	0.516>0.05 insignificant difference
Do you use mouthwash? ○ Yes ○ No	0.278>0.05 insignificant difference
When did you last visit the dentist for dental scaling? ○ since three months ○ since six months ○ since a year ○ more than a year ○ I've never visited a dentist before	0.118>0.05 insignificant difference
How many glasses of water do you drink per day? ○one glass ○two glasses ○three glasses ○four glasses ○more than four glasses	0.454>0.05 insignificant difference
Are you a smoker? ○ Yes ○ No	0.883>0.05 insignificant difference

Laboratory analysis

The laboratoryanalysis results of the four drinking water samples for calcium(Ca) and phosphate (PO_4) mg/L ppm were as the following (Table 4): Sample 1. Bottled water from a Saudi water factory. Riyadh, KSA. (PO_4) <0.1 mg/L ppm

(Ca)=16.5 mg/L ppm. According to the bottle label, magnesium was (Mg) =2.4 mg/L ppm.
Sample 2.Tap water. Al-Jubail, Eastern Province, KSA. (PO_4) =0.1 mg/L ppm(Ca)=16 mg/L ppm. Sample 3. Water from a well with a desalination home device. Al-Hofuf, Eastern Province, KSA. (PO_4) =0.1 mg/L ppm (Ca) =4.8 mg/L ppm. Sample 4. Water from a truck refilled in a water refill station. Riyadh, KSA. (PO_4) =0.3 mg/L ppm (Ca) =87 mg/L ppm.

Table 4: Laboratory analysis for (Ca) and (PO_4) mg/L ppm

Sample ID	(PO_4) mg/L ppm	(Ca) mg/L ppm
Bottled water from a Saudi water factory. Riyadh, KSA.	<0.1	16.5
Tap water. Al-Jubail, Eastern Province, KSA.	0.1	16
Water from a well with a desalination home device. Al-Hofuf, Eastern Province, KSA.	0.1	4.8
Water from a truck refilled in a water refill station. Riyadh, KSA.	0.3	87

Discussion

Saliva pH level and its saturation with calcium and phosphate are important in the process called remineralization.[2,8] Bardow et al. studied saliva with respect to its inorganic components (calcium and phosphate)which play a positive role in the process of remineralization when being near normal concentrations with a pH level near neutral in the oral environment.[9] Early theories of calculus formation were based on precipitation of calcium phosphate by various mechanisms such as elevation in local pH and phosphate activity with plaque serving as passive receptacle for the precipitate. Now, it appears that mineralization often occurs in the inner layers of the plaque, and dental calculus is produced in the presence of bacteria more than their absence.[10] Furthermore, Wong et al. indicated that alkaline pH is critical in promoting plaque mineralization and that mineral deposition is modulated by serum. In the study of Wong et al., it was found that calcium phosphate deposition was proportional to the plaque resting pH.[11]

Individual oral hygiene practices are required to be regular and sufficient for a healthy dental and periodontal condition. While it is sufficient to stop or interrupt individual oral hygiene practices for a short-term for the formation of soft accessories such as debris and bacterial plaque on tooth surfaces, a long-term negligence of the oral hygiene is required for the formation of dental calculus.[12] In some highly susceptible individuals to dental calculus formation, it is possible for regrowth of calculus to occur within two weeks of professional scaling and oral hygiene instructions. However, continuous and gradual inhibition of calculus regrowth in susceptible individuals could be achieved with repeated professional prophylaxis and enhanced compliance with oral hygiene care.[6]

Magnesium (Mg) is the other hardness determinant in addition to calcium.[13]Magnesium inhibits the formation of dental calculus with its calcium channel blocking effect.[14]Also, it inhibits the formation of dental calculus by reducing and preventing the undesirable effects of phosphate in the sense of creating stones.[15] Of the aforementioned calcium phosphate crystals, only whitlockite contains magnesium which substitutes for part of the calcium in whitlockite.[4,16] Magnesium inhibits apatite originating from amorphous calcium phosphate to the benefit of whitlockite (magnesium whitlockite) formation.[16] Therefore, magnesium inhibits the formation of dental calculus. The Healthy Water Association (HWA) standard calls for bottled water to provide a minimum of 25 mg of magnesium per liter and suggests that the ratio of calcium to magnesium in bottled water should not be greater than 2-to-1. Some researchers suggest a more balanced 50-50 ratio between calcium and magnesium where excessive calcium is dangerous.[17]

Criteria for total phosphorus in water as recommended by US EPA (1986)[18]

1. No more than 0.1 mg/L ppm for streams which do not empty into reservoirs 2. No more than 0.05

mg/L ppm for streams discharging into reservoirs
3. No more than 0.025 mg/L ppm for reservoirs

Phosphate-phosphorous levels for rating a water sample quality[18,19]

0.01-0.03 mg/L - the level in uncontaminated lakes

0.025 – 0.1 mg/L - level at which plant growth is stimulated

0.1 mg/L - maximum acceptable to avoid accelerated eutrophication

>0.1 mg/L -accelerated growth and consequent problems

The results of this study were consistent with literature and showed that Eastern Province that had higher alkaline saliva pH (34.9%) than Riyadh (28.3%) had higher calculus risk than Riyadh too. The observations of Bergström study indicated a strong association between tobacco smoking and both supragingival and subgingival calculus deposition,[20,21] but there was an insignificant difference between Riyadh and Eastern Province in tobacco smoking. Also, there was an insignificant difference between Riyadh and Eastern Province in oral hygiene habits (tooth brushing, dental flossing, mouthwash), the last visit for dental scaling, and the amount of daily water consumption. However, the results of this study showed that there was a statistically significant relationship between the type of drinking water and dental calculus as well as between provinces and dental calculus. In addition, there was a significant difference between the two provinces in the type of drinking water where Eastern Province depended more on water from trucks (34.2%) than Riyadh (7.9%) while Riyadh depended more on bottled water (72.4%) than Eastern province (48.7%). By comparing the lab analysis results of the water from a truck sample and bottled water sample with the criteria for total phosphorus in water recommended by US EPA, the quality of the bottled water sample appeared to be better.

The aforementioned results of this study indicate that drinking water influences dental calculus occurrence and severity in Saudi Arabia.

Conclusion

The results of this study indicate that drinking water influences the occurrence and severity of dental calculus. It's recommended to monitor drinking water quality by performing periodic checkups and analyses. Furthermore, it's important to comply with the international standards of calcium (Ca) and phosphate (PO_4) concentration mg/L ppm in drinking water taking into consideration the importance of magnesium (Mg) and the ratio of calcium to magnesium which ideally should not be more than 2-to-1.[17]

Funding: None

Conflict of interest: None declared

References

1. Greene JG, Vermillion JR. The simplified oral hygiene index. *J Am Dent Assoc*. 1964;68(1):7-13.
2. Łagocka R, Bochińska JS, Noceń I, Jakubowska K, Góra M, Radlińska JB. Influence of the mineral composition of drinking water taken from surface water intake in enhancing regeneration processes in mineralized human teeth tissue. *Pol J Environ Stud*. 2011;20(2):411-416.
3. Mills CA. Factors affecting the incidence of dental caries in population groups. *J Dent Res*.1937;16(5):417-430.
4. Jin Y, Yip HK. Supragingival calculus: formation and control. *Crit Rev Oral Biol Med*. 2002;13(5):426-441.
5. Friskopp J, Isacsson G. A quantitative microradiographic study of mineral content of supragingival and subgingival dental calculus. *Eur J Oral Sci*. 1984; 92(1):25-32.
6. Galgut PN. Supragingival calculus formation in a group of young adults. *Quintessence Int*. 1996;27(12):817-820.
7. Tanzer JM, Grant LP, McMahon T, Clinton D, Eanes ED. Simultaneous caries

induction and calculus formation in rats. *J Dent Res*. 1993;72(5):858-864.
8. Ten Cate JM, Larsen MJ, Pearce EIF, Fejerskov O. Chemical interactions between the tooth and oral fluids. In: Fejerskov O, Kidd E, editors. *Dental Caries: The Disease and Its Clinical Management*. 2nd ed. Oxford: Blackwell Munksgaard; 2008:209-231.
9. Bardow A, Lagerlöf F, Nauntofte B, Tenovuo J. The role of saliva. In: Fejerskov O, Kidd E, editors. *Dental Caries: The disease and Its Clinical Management*. 2nd ed. Oxford: Blackwell Munksgaard; 2008:189-207.
10. Hammond BF. Intraoral causes of periodontal disease. In: Goldman HM, Cohen DW, editors. *Introduction to Periodontics*. 5th ed. Saint Louis: Mosby; 1977:121-168.
11. Wong L, Sissons CH, Pearce EI, Cutress TW. Calcium phosphate deposition in human dental plaque microcosm biofilms induced by a ureolytic pH-rise procedure. *Arch Oral Biol*. 2002;47(11):779-790.
12. Arabaci T, Demir T. An index developed for the determination of oral hygiene motivation success. *Dent Hypotheses*. 2013;4(1):9-12.
13. Calcium and water: reaction mechanisms, environmental impact and health effects. Lenntech. https://www.lenntech.com/periodic/water/calcium/calcium-and-water.htm. Accessed April 24, 2018.
14. Kidney stones. Mg12.info-Magnesium Online Resource Center. http://www.mg12.info/articles/kidney-stones.html. Accessed April 24, 2018.
15. Luoma H, Nuuja T. Caries reduction in rats by phosphate, magnesium and fluoride additions to diet with modifications of dental calculus and calcium of the kidneys and aorta. *Caries Res*. 1977;11(2):100-108.
16. Lagier R, Baud CA. Magnesium whitlockite, a calcium phosphate crystal of special interest in pathology. *Pathol Res Pract*. 2003;199(5):329-335.
17. Sardi B. Minimum magnesium standard for drinking and bottled water would save 150,000 lives annually. Mg Water-The Magnesium Web Site. http://www.mgwater.com/minimum.shtml. Published June 16, 1999. Accessed April 24, 2018.
18. Oram B. Phosphates in the environment. Water Research Center. https://www.water-research.net/index.php/phosphates. Accessed May 1, 2018.
19. Wojcik W. Phosphate cycle. Organic Earth Solutions. http://www.organicearthsolutionsllc.com/phosphate-cycle/. Published December 22, 2012. Accessed April 25, 2018.
20. Bergström J. Tobacco smoking and supragingival dental calculus. *J Clin Periodontol*. 1999;26(8):541-547.
21. Bergström J. Tobacco smoking and subgingival dental calculus. *J Clin Periodontol*. 2005;32(1):81-88.