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FLUORIDE CONCENTRATION AND OTHER ELEMENTS IN TOOTH STRUCTURE AND ITS EFFECT ON DENTAL CARIES IN KIRKUK, IRAQ

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ABSTRACT

The study involved the determination of fluoride and other elements like Mn, Na, Mg, Si, K, Ca, Fe, Al, Cl and some trace elements (Cr, Cd, Ni, Zn, Pb, Sr, As, Co, Cu, Mo and Se) in 220 teeth samples with age group ranging from 6–45 year. The average concentration of fluoride in samples were less than the global average, and the total contents of fluoride in the children deciduous teeth are relatively higher than that of permanent teeth. The infection rate of dental caries in children seen in age between 6–11 years and increasing after the age of 12 due to certain environmental factors, age, water and food quality, so there is a strong relationship between the rising amount of fluoride concentration in the area and reducing the rate of dental caries. The study also determines the different limits and importantly the optimum value of fluoride concentration in drinking water of Kirkuk City which is done by correlation with the mean value of the maximum daily temperature of the city over the last five years, and also taking in consideration that human gets the fluoride from a different source such as food, air and tooth paste, so we correlate our finding with the rate of fluoride taken from other sources which not greater than 6mg/day, according to World Health Organization (WHO), in order to avoid the hyper fluorosis (excess fluoride).

Keywords: Dental carrier; Fluoride; Kirkuk; Tooth; Temperature

INTRODUCTION

Fluoride is one of the important chemical elements in the growth of the human body, especially his teeth, also for the integrity of the bone (Oruc, 2008). There is a strong relationship between the geochemical effect of the fluoride in the water and bone, teeth poising, but the direct effect of

the fluoride on bone growth, problems in the respiratory, elementary systems still under trials and in the researches stage. Dental caries and dental fluorosis take place when there is any deviation of fluoride ion from its ideal levels, so the low steady level of the ion in the oral cavity should be kept continuously to get sound healthy teeth, on the contrary to what be known previously as the level of this ion should be kept in good levels only in the period of teething regarding the benefit of it of on enamel. Developed countries are providing Fluoride to teeth throw water supply and tooth paste (Avci et al., 2009). Fluoride ion is found in rivers (fresh water), saline water (sea water), soil, rocks, vegetables (mostly green), milk and fish (Sultan et al., 2014; Al-Hamadani et al., 2016a; Al-Hamadani et al., 2016b). The fluoride is a trace element and as the test of trace element if has a narrow range in human body WHO (2002), Table 1 shows the effect of different concentrations of the ion in drinking water on human body and the problem caused by those concentrations (WHO, 2018).

Table 1. Effect of fluoride ion in drinking water on health (WHO, 2018)

Fluoride concentration in drinking water (mgl^{-1})	Health effects
0.0 – 0.5	Weak growth, fertility, and tooth decay
0.5 – 1.0	Promote healthy teeth leading to correct teeth
1.0 – 4.0	Preventing dental decomposition (caries)
4.0 – 10.0	Dental fluorosis (Teeth Whitening)
Greater than 10.0	Dental fluorosis, skeletal toxicity of fluoride (pain in the back and neck), fluoride paralysis.

Health Effect of Fluoride

The human tooth consists of enamel, dentin, cementum, which are formed by hydroxyapatite, water and protein (Harris, 2009). The outer layer of tooth is thin and transparent covering the dentin and protecting it. The dentin regarded the most solid part in human which consist of inorganic mineral compounds, 30% water, 10% organic compounds. The dental caries starts first by demineralization of enamel hydroxyapatite which is caused by the bacterial formation of organic acids from remnants of food, by increasing of hydrogen ion which causes a decrease in the pH of oral cavity and these hydrogen ions emerge with hydroxide ion which present in Enamel forming water leading to demineralization and destruction of this layer (Akgün et al., 2012). Dental fluorosis is a disturbance in enamel due to frequent exposure to high concentration of fluoride ion during growth and this intensity of fluorosis depends on the time of exposure, the patient response, and his weight, physical activity, nutritional factor and his bone growth (Den,

1994; EPA, 2008; Buchel et al., 2011). The increase of fluoride concentration in drinking water above the limit which is allowed, show many bad effects on long term including sever hyper fluorosis, osteopenia (Fawell et al., 2006). Other factor that increases the person ability for fluorosis is increase the florid ion concoction in environment, malnutrition and renal impairment (Akosu and Zoakah, 2008). The change taking place in the permeant teeth is the most dangerous changes and the critical period for children's to be affected by fluorosis is between 1-4 years, and start to decrees in the age of eight (Rodrigues et al., 2002; Mann el al., 1990), most of researches showing that male is more affected than female, and children are more affected than adult (Rodrigues et al., 2002; Mann et al., 1990; Mascarenhas and Burt, 1998; Ramires et al., 2007; Krishnamachari and Sivakumar, 1976; Karthikeyan and Shanmugasunder, 2000).

MATERIALS AND METHODOLOGY

Fluoride and Elements Concentration Measurement in Tooth Samples

Two hundred twenty dental samples were collected from different age groups through visits to health centers and private dental clinics within the city of Kirkuk, 20 of which were selected for laboratory analysis (Table 2). The dental samples were ground into fine powder in an agate mortar. The samples were sieved to pass through of 200 μm, and then pressed into thick pellets of 32 mm diameter using wach as blinder. USGS standards, GEOL, GBW 7109 and GBW-7309 sediment equally pressed into pellets in a similar manner as the samples, and these used for quality assurance (Timothy, 1989; Johnson et al., 1999). Multi-element concentration was determined by using polarized energy dispersive XRF. The spectrometer used in this study was Thermo Scientific - ARL PERFORM'X spectrometer which was equipped with a Rh anode X-ray tube, 0.5mm Be side window in Bozok University BİLTEM Research Center laboratories, Turkey. The detector of spectrometer is Si by liquid N_2 cooled with resolution of < 250eV at Mn Kα, 5000 cps. Total analysis time for each addition element was 60 min. The sample measurements by Thermo Scientific - ARL PERFORM'X mainly done by three types of targets.

Fluoride Concentration Measurement in Drinking Water Samples

Twenty samples of drinking water were taken from different parts of Kirkuk. Fluoride concentration in drinking water samples was determined with a combination fluoride selective electrode (ISE-BNC), against silver/silver chloride reference, after adding total ionic strength adjustment buffer (27503-13 F) coupled with anion analyzer (WTW, model in Lab pH/ION 735, GmbH Company). Owing to its simplicity and short analysis time, the fluoride ion selective

electrode is widely used for the determination of F. Before determining the fluoride contents, equal volume quantities of total Ionic Strength Adjustment Buffer (TISAB) were mixed with all samples. The TISAB contains an acetic acid/acetate buffer that fixes the pH of the solution at about 5. At this pH, the formation of HF and the concentration of OH^- are negligible. Other anions detectable by the electrode are insignificant. It also contains NaCl to create a high and constant ionic strength and a complexing agent that removes cations that could interfere by forming complexes with fluoride. Fluoride standards ranging from 0.020 - 0.500 mg L^{-1} fluoride were used to calibrate the measurement.

RESULTS AND DISCUSSION

Fluoride and Chemical Elements Content Within Dental Samples

In this study which included 1280 patients, 966 of them were diagnosed having dental problems, (75%) of the patient having dental caries, 65% of them were adult while 35% were children, no dental fluorosis was detected in any case included in our study. The dental caries in age group (6-11y) was reaching 42% while in age group older than age 12 years and occurred mostly in molar teeth, this type of caries was less in younger age group. Table 3 shows the mean and standard deviation for fluoride. other trace elements concentration which reach to 9-24ppm with range of 14.59 ppm, while Schirber (2009) show less range of fluoride concentration in the teeth and bones reaching to 37ppm, Beyhan (2003) shows contraction of same ions reaching to 2-3g inside teeth and bone structure. The Ten Cate and Featherstone (1996) show that the outer layer of enamel of tooth reach to about 3000µg/g in comparison to concentration of 100µg/g in the joint paint between enamel and dentin. Table 2 also shows that the total concentration of fluoride ion, it was higher in children than adult, so its reaching to 14-24 ppm with range of 19.14 ppm in 6-11-year age group, ranges from 14.50 ppm in 2-19 year age group, while its 9-13 ppm with range of 11.5 ppm in 22-29 year age group, and finally reached 8-21 ppm with range of 13.20 ppm in 33-45y age group. Different age groups show different environmental differences, so after birth in early years of life, the mouth only containing the soft tissue and all of those keeping the moisture by the salivary glands secretion which are free, from bacteria casing the caries and they keep the pH inside oral cavity this will encourage the rapid absorption of florid during the period of rapid growth of teeth and bones in childhood and this will explain the relative increment of fluoride concentration in the deciduous teeth of the children less than 12year of age and relative decrement of caries in decides tooth (Table 2).

Table 2. Average fluoride ion concentration in teeth within the study area

No.	Samples	Age (year)	Fluoride Concentration (ppm)	Dental Status	Average Concentration of Fluoride (ppm)
1	D15	6	22	Sound tooth	19.14
2	D18	6	24	Sound tooth	
3	D10	7	16	Sound tooth	
4	D13	8	19	Sound tooth	
5	D17	9	21	Sound tooth	
6	D2	10	14	Sound tooth	
7	D1	11	18	Sound tooth	
8	D11	12	9	Carious tooth	14.50
9	D12	16	14	Carious tooth	
10	D3	17	20	Carious tooth	
11	D16	19	15	Carious tooth	
12	D9	22	13	Carious tooth	11.50
13	D4	23	9	Carious tooth	
14	D19	27	11	Carious tooth	
15	D5	29	13	Carious tooth	
16	D8	33	8	Carious tooth	13.20
17	D6	30	21	Carious tooth	
18	D7	35	18	Carious tooth	
19	D20	40	9	Carious tooth	
20	D14	45	10	Carious tooth	

After the age of 12y, there is increase in dental caries because of many factors which are changed inside oral cavity e.g. the type of food, water supply, the motivation about the dental health, because the caries took place because the formation of food particles between the teeth and forming the organic acids which cause the demineralization and caries. Ali and Abdulrahman (2016) show that the fluoride ion concentration in Kirkuk city ranging between 0.01-0.289 ppm and they noticed a relatively partial relationship between ion concentration in water supply and dental caries. The study showed that the highest contraction was in Athar and Huzairan region which reach to 22pm range of 0.146 ppm and 24ppm with range of 0.319 ppm respectively, these number were due to usage of water from well and tap water for their drinking. In regions like Arafa and Tisin, the recorded concentration was reach to 20ppm. The least concentration for the ion was registered in regions depending only on tap water for drinking (Fig. 1) and (Table 2). There is a strong relationship between the ion concentration and dental health. For studying the correlation between total fluoride concentration with same major and minor elements like (Na, Mg, Si, K, Ca, Fe, Al, Cl, Mn) and trace elements like (Cr, Cd, Ni, Zn, Pb, Sr and As) (Table 4).

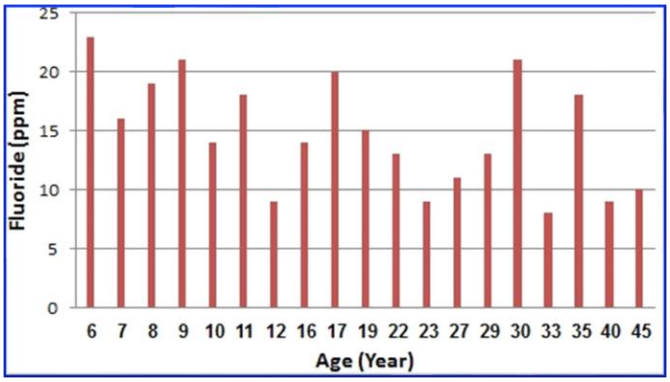

Figure 1. Relative distribution of fluoride from different age in the tooth samples

Table 3. Statistics of total fluoride, and elements in the teeth samples

Elements	Range	Mean	Standard Division
Na (%)	0.08-0.20	0.092	0.035
Mg (%)	0.013-0.262	0.035	0.049
K (%)	0.055-0.411	0.143	0.033
Ca (%)	3.252-38.927	11.872	6.231
Fe (%)	0.001-0.022	0.008	0.004
Al (%)	0.100-0.869	0.267	0.182
Cl (%)	0.019-0.372	0.055	0.023
Mn (%)	0.0002-0.001	0.0005	0.0002
Cr (%)	0.0003-0.005	0.001	0.001
Si (%)	1.24-5.08	1,389	1,005
P (%)	1.431-15.987	3.972	2.992
F (ppm)	9-24	14.585	4.226
Cd (ppm)	0.65-8.95	1.958	0.938
Ni (ppm)	1.05-62.81	8.225	9.247
Zn (ppm)	18.17-9287	558.241	2.0085
Pb (ppm)	0.82-45.8	7.238	9.134
Sr (ppm)	33.82-987	204.112	2.4228
As (ppm)	0.22-28.24	2.45	5.968
Co (ppm)	0.91-5.34	1.957	0.995
Cu (ppm)	0.98-15.47	7.421	2.663
Mo (ppm)	3.02-24.15	6.79	3.972
Se (ppm)	0.33-1.75	0.387	0.295

Table 4 shows a stronger correlation between these minerals and teeth concentration at the confidence level of 95.5% and depending on 0.37 of r value JOHN (2002). A strong positive relationship between the fluoride ion and all the major elements except Fe was observed, this study agrees with the findings of the Al-Luhaibi, 2017. Most of these elements forming the chemical structure of the tooth in which the fluoride is concentrated in hard solid part of enamel

forming mineral compounds, forming fluorapatite (Ca5(PO4)3(OH, F, Cl) when present in the fluid with calcium and phosphate.

Table 4. Correlation coefficient between fluoride and elements in the teeth of studied area

	Na	Mg	K	Ca	Fe	Al
F	0.226	0.305	0.341	0.273	-0.029	0.222
	Cl	Mn	Cr	Si	P	Cd
F	0.297	0.335	0.207	0.287	0.259	0.311
	Ni	Zn	Pb	Sr	As	Co
F	0.213	-0.210	0.0323	-0.101	-0.221	0.065
	Cu	Mo	Se	*Correlation is significant at level (95.5%).		
F	-0.089	0.284	0.156			

There are elements like calcium, fluoride in the body forming non soluble compounds with fluoride which decrees its absorption by the bones and teethes (Cerklewski, 1997). In spite of this the effect of calcium become diminished if it's found in form of monophosphate fluoride, also there is a positive relationship between fluoride ion and sodium (0.295) the fluoride could be presented as sodium fluoride in the studied samples done by Villa et al., (1992). Reyes-Gasga et al., (1997); Gutiérrez-Salazar and Reyes-Gasga, (2003) illustrated that there is a positive relationship between F, Na, Cl and Mg compounds of these elements which are found in very little amounts in tooth enamel and dentin. There is weak positive relation between fluoride with aluminum (0.214) studies of Lubkowska et al., (2002) and Ahn et al., (1995) mentioned that Al prevent the absorption of fluoride by disturbing the metabolism of phosphorous, calcium and magnesium. A weak positive relation of fluoride with trace element (Cr, Ni, Pb, Co, Se) was determined, also a negative relationship of fluoride with Zn, Sr, As and Cu, most of these trace elements reaching the enamel, dentine irregularly through blood vessels inside them (Budd, 2000). The fluoride also has a positive correlation with cadmium reaching to 0.305 and this element founded in emigrates, phosphate fertilizers, minerals waste, dyes industry, also present as trace amount in food (e.g. vegetables, potato, wheat and barley) also presented in liver and kidney tissue, this element has a connection with dental caries and this fact explain the relation of dental caries with content of Cd inside the tooth (Arora et al., 2008; Amr and Helal, 2010).

Dental Health and The Ideal Content of Fluoride in Drinking Waters

The environmental protection agency (EPA) recommended that the concentration of fluoride ion in drinking water should be ranging between 0.7 – 1.2 ppm because presence of ideal level of this ion in the water will decrease dental caries and prevent the dental fluorosis as mentioned by (Ali

and Abdulrahman, 2016; Mackenzie and David, 1991). The fluoride ion ideal concentration depends mainly on the climate of the geographical area included by the study, so there is a reverse relationship between the fluoride ion and the degree of temperature, so when there is a high temperature climate in a certain city or area, the ideal concentration of the ion is less than other areas and vice versa is true, and this because in hot climate the people drink more water so concentration will increase accordingly to that.

Many studies such as Fawell et al., (2006), proved that increase concentration of the fluoride ion more than the ideal level for a long term have dangerous effect on human body such as fluorosis in the teeth and bones. WHO (2008) determined the ideal level of the fluoride ion in drinking water by 1.5 mgl^{-1} and in Iraqi standards level is 1.0 mgl^{-1} (WHO, 2006; Indermitte et al., 2009). According to the (EPA) the ideal level should range between 0.7 – 1.2 mgl^{-1} (Viessman and Hammer, 1985). Inspite of the warring and instructions of WHO and other organizations concerned by general health, the levels of fluoride ion is exceeds the ideal concentration because high temperature will cause drinking too much water (Brouwer et al., 1998), so depending on the climate of any city we can determine the real idea concentration of fluoride ion in this area for the last five years (Al-Anaz and Abawi, 2006). The highest number of average rate of temperature in last five years for Kirkuk city was estimated by 29.51 C^0 and when we compare this degree with the highest degree of annual average rate of temperature, we can determine the upper and lower limit of ideal concentration of fluoride ion in drinking water in the area included by our study and it is 0.6, 0.8 and 0.7 respectively (Tables 5 and 6).

Table 5. Highest averages of temperature in last five years at Kirkuk (Al-Luhaibi, 2017)

Years	**2011**	**2012**	**2013**	**2014**	**2015**	**Average**
Months						
January	14.00	14.00	14.00	16.00	15.00	14.60
February	16.00	16.00	18.00	19.00	18.00	17.40
March	22.00	18.00	22.00	23.00	22.00	21.40
April	27.00	30.00	29.00	29.00	28.00	28.60
May	34.00	36.00	33.00	36.00	36.00	35.00
June	41.00	42.00	40.00	41.00	41.00	41.00
July	44.10	44.10	43.50	43.80	45.60	44.22
August	43.20	43.20	43.20	44.70	44.70	43.80
September	38.40	39.30	38.70	38.60	38.60	38.72
October	29.60	32.00	31.20	30.70	33.10	31.32
November	19.40	23.20	23.30	21.40	21.30	21.72
December	17.00	16.60	14.80	17.30	16.10	16.36
Average	28.81	29.53	29.23	30.04	29.95	**29.51**

It should consider the other sources of fluoride which can come from food, air and tooth paste, also there are personal difference which range between 0.05 – 7.51 mg according to WHO (2002), these differences could be due to difference in food and water intake by each person. The WHO determine the ideal level with concerting the personal variation in food and water intake so the ideal level should be lowered accordingly if these levels approaching to more than 6 mg / day that take from other source (WHO, 2004).

Table 6. Limits of ideal concentration of fluoride in drinking water in the studied area

Annual average of upper atmospheric temperature by C^0 (best on atmospheric temperature rate for last five years)	Fluoride concentration (mg/l)		
	Confirmed limits		
	Minimum	Ideal	Maximum
10.0 - 12.05	0.9	1.2	1.7
12.11 - 14.61	0.8	1.1	1.5
14.66 - 17.66	0.8	1.0	1.3
17.72 - 21.44	0.7	0.9	1.2
21.5 - 26.22	0.7	0.8	1.0
26.27 - 32.5	0.6	0.7	0.8

CONCLUSIONS

1. The studied fluoride ion (14.59 ppm) is lower than the in tooth and bone (37 ppm).
2. The total content of fluoride in deciduous teeth is relatively higher than the level in permeant teeth; also, the tooth caries is more in age group of 12 years and more.
3. A higher concentration of fluoride is founded in samples of the patient depending on mixed water supply (tap waters and well waters) while the concentration was lower in patients depending only on tap water for drinking.
4. There is a negative correlation between the fluoride and trace elements except cadmium.
5. During the determination of ideal levels of fluoride concentrations, we should concede the other source of the ion like food, air and tooth pastes.

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