Concentrations of selected elements in permanent teeth and enamel among a group of adolescent girls in relation to severity of caries

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ABSTRACT

Background: Human teeth considered to be an important etiological host factor in relation to dental caries through its morphology and composition. Elements may incorporate in tooth structure during pre and post-eruptive period changing the resistance for caries. The aims of this study were to determine the concentration of selected major (Calcium and phosphorus) and trace elements (Ferrous iron, nickel, chromium and aluminum) in permanent teeth and enamel among a group of adolescent girls in relation to severity of dental caries

Material and Methods: The study group consisted of 25 girls with an age of 13-15 years old referred by Orthodontists for extractions of upper first premolars (two sides). Tooth and enamel samples were prepared for chemical analysis according to method described by Lappalainen and Knuttila (1979). Dental caries was diagnosed by both clinical and radiographical examinations following the criteria of D_{1-4}MFS index described by Muhlemann (1976). All data were analyzed using SPSS version 19.

Results: The concentration of major elements in teeth and enamel (measured in % of dry weight) showed that Ca ions were higher than P ions. On the other hand the concentration of trace elements in teeth and enamel samples (measured in ppm) showed that Al ions was the highest followed by Ferrous Fe then Ni ions, while Cr ions were the least in concentration. All elements showed statistically highly significant difference in concentration between teeth and enamel samples. Ca/P ratio was higher in enamel than tooth, but the difference was statistically not significant. Major elements (calcium and phosphorus) in tooth and enamel samples recorded negative correlations with DMFS. Trace elements except chromium ions recorded positive correlations with DMFS. They were not significant except for nickel ions in tooth and aluminum ions in enamel.

Conclusions: The presence of these elements in both teeth and enamel samples indicated that these elements present in our environment; as foods, water, and air so they incorporate through out the tooth layers during the pre-eruptive period of tooth development, and incorporate the outer enamel surface during the demineralization and remineralization processes that occurs in the post-eruptive periods. Ca and p ions play an important role in mineralization of tooth and enamel. Cr ions may play a role in improving mineralization and crystallity of teeth, while Fe, Ni and Al may act as cariogenic elements.

Key Words: Trace elements, Permanent teeth and enamel, Caries severity. (J Bagh Coll Dentistry 2013; 25(1):176-180).

INTRODUCTION

The tooth is considered to be the most etiological host factor in relation to dental caries through its morphological characteristics and composition, so chemical analysis of teeth for their major and trace elements may allow understanding of the increase and decrease in their susptability to dental caries [1, 2].

Incorporation of trace elements during mineralization has been recorded to affect the resistance to dental caries [3, 4]. Fluoride was reported to decrease dental caries, while the role of other trace element in the prevention of the disease is not well substantiated. Several studies in Iraq were conducted concerning chemical constitution of teeth in relation to dental caries and a controversy was reported [5- 7] .

For all of the above and in order to increase the knowledge about the inorganic elements and dental caries etiology, this study was designed.

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MATERIALS AND METHODS

Patients involved in this study were those referred by Orthodontists for extractions of upper first premolars (two sides). The total number of patients was 25 girls with an age rang of 13-15 years, recorded according to the last birthday [(8)]. Examinations were carried out in the specialized dental center in Al-Sader City and the specialized center for Prosthodontic and Orthodontic treatment in Al-Qaira in Baghdad province under standarized conditions [(8)]. Dental caries was diagnosed by both clinical and radiographical examinations. The clinical examination of teeth surfaces was done by using dental mirror and sharp dental explorer. Assessment and recording of caries experience was done by the application of (D_{1-4} MFS index for permanent teeth) [(9)]. At the end of caries examination patient was anesthetized for extraction of the upper first premolars cited by the orthodontist. After extraction teeth were cleaned and polished firstly by pumice slurry and rubber cup using slow speed hand piece, then washed with de-ionized water. The right upper 1st premolar of each patient was prepared by separating the root from its crown using curbide fissure burs number 36/19, and then dentine was removed from enamel by diamond round burs number 1/18 [6].Then the prepared enamel and the whole left upper 1st premolar were prepared for chemical analysis [10]. Tooth and enamel samples were dried at 105 ºC for 6-8 hours to a constant weight, then powdered using ceramic mortar and pestle**.** Samples of 250 mg of tooth powder and enamel powder were dissolved in 2ml of concentrated HCl and 1ml of concentrated HNO_3**.** Following dissolution of samples they were diluted with 5 ml de-ionized water then filtered by using of pre- weight filter (Cinter silica filter). After filtering the volume was completed to reach a final of 25 ml. The filter was re-weighted again following dryness and the final weight of the dissolved tooth powder was determined. Chemical analysis was carried out at Poisoning Consultation Center, Medical city. Calcium, aluminum, nickel and chromium ions were determined using Air-acetylene Atomic Absorption Spectrophotometer (AAS) using standardized procedure by air-acetylene, while inorganic phosphorus and iron were determined color- metrically by using chemical kits.

SPSS version 19 (Statistical Package for Social Sciences) was used for statistical analysis. Descriptive measurement (mean and standard deviation) were used to describe variables. Student's t-test was used to test the statistical significance of difference in mean of elements' concentrations between tooth and enamel samples. The statistical significance, directions and strength of linear correlation between the concentration of element in each sample and values of D_{1-4}MFS index was measured by Person's correlation coefficient. Multiple linear regressions between dependant variable (dental caries) and independent variable (concentration of elements) were applied. P value equal to or less than 0.05 level of significance ($P \leq 0.05$) was considered to be statistically significant, P value equal to or less than 0.01 level of significance ($P \leq 0.01$) was considered to be statistically highly significant. The confidence limit was accepted at 95%.

RESULTS

Decayed, missed and filled teeth surfaces of girls by fractions of D_{1-4}MFS index were represented by their means and standard deviation (SD) in Table (1). Clinical and radiographical examinations showed that all subjects were affected by dental caries. The decayed surfaces (DS) contributed the major parts of this index followed by filled surfaces (FS) then missed surfaces because of caries (MS). Grade (2) of lesion severity was the highest one, while the frank cavitation; grade (4) was the lowest one.

Table (2) illustrates the concentration of elements in teeth and enamel samples (Mean ± SD) with statistical differences between them. The concentration of major elements in teeth and enamel (measured in % of dry weight) showed that Ca ions were higher than P ions. On the other hand the concentration of trace elements in teeth and enamel samples (measured in ppm) showed that Al ions was the highest followed by Ferrous Fe then Ni ions, while Cr ions were the least in concentration. All elements showed statistically highly significant difference in concentration between teeth and enamel samples. Ca/P ratio was higher in enamel than tooth, but the difference was statistically not significant.

Pearson's correlations coefficient between caries- experience and elements concentration in teeth are seen in Table (3). Negative, weak and statistically not significant correlations were recorded between major elements (Ca and P ions) in teeth samples and DMFS. Regarding trace elements in teeth sample Al ions recorded a positive, weak and statistically highly significant correlation with D_3 (P= 0.01); on the other hand Ni ions recorded a positive, weak and statistically significant correlation with DMFS (P=0.05). Generally the correlations between other elements (major and trace elements) measured in the teeth in addition to Ca/P ratio with caries- experience were all statistically not significant where as some of them showed positive correlations, while others showed negative correlations.

Table (4) illustrates the correlation coefficient between elements (major and trace) in enamel with caries-experience. Major elements in enamel samples showed a negative, weak and statistically significant correlation between P ions and DMFS (P= 0.05), while statistically not significant correlation was seen with Ca ions. For trace element Al ions recorded a positive, strong and statistically highly significant correlation with DMFS (P 0.01), Al ions also showed a positive, weak and statistically significant correlation with D_1 (P= 0.01). While other elements (major and trace elements) measured in enamel in addition to Ca/P ratio in enamel recorded statistically not significant correlation with caries**-** experience.

Table (5) illustrates the result of MLR for DMFS surfaces (dependent variable) explained by elements measured in teeth samples (independent variables). A complete correlation coefficient of 0.565 was recorded between the DMFS and all factors entered. The R^2 value of 0.320 was recorded indicated that 32 % of changes occurred in DMFS were explained by inorganic composition of teeth. For major elements the highest beta- correlation was recorded for Ca/P ratio followed by P then Ca. For trace elements the highest beta-coefficient was recorded for Ni ions followed by Cr then Al and finally Fe ions. No one of these beta- coefficients was recorded to be statistically significant (P 0.05).

Table (6) illustrates the result of MLR for the DMFS (dependant variable) explained by elements measured in enamel samples. A complete correlation coefficient of 0.754 was recorded between DMFS and all factors. The R^2 value of 0.569 was recorded indicated that 56.9 % of changes occurred in DMFS were explained by the inorganic composition of enamel. For major elements beta- coefficient recorded for Ca ions was the highest followed by that recorded for Ca/P ratio and finally for P ions. For trace elements Al ions recorded the highest beta-coefficient followed by Ni then Fe and finally for Cr ions. Beta- coefficient for Al ions was highly significant (P 0.01), while other beta-coefficients were recorded to be not significant (P 0.05).

DISCUSSIONS

Different types of elements may incorporate in pre- eruptive and post-eruptive stages of tooth development, changing the resistance against dental caries [11, 12].

Incorporation of elements through layers of enamel and dentine may affect the rate of progression of dental caries, while incorporation of others following eruption involve the outer enamel surface, may affect initiation of dental caries. For this reason dental caries by grades of lesion severity was explored by the present studied. The D_{1-4}MFS index was applied, as D_1 and D_2 fractions indicated that lesion is in the outer enamel surface, which may or may not progress in the deeper layers of tooth, while D_3 and D_4 fractions indicated that caries was already progressed to the deeper tooth layer.

According to the results of this study the concentration of Ca ions in both tooth and enamel samples were higher than P ions. This was true since these two ions are the major elements of the inorganic composition of tooth that form the apatite crystals with chemical formula [$Ca_{10}(PO_4)_6(OH)_2$] [13, 14]. The Ca/P ratio of both tooth and enamel samples was lower than that of pure synthetic hydroxy apatite crystals that is 2.15 indicating the incorporation of other elements that replacing Ca ions of these crystals resulting in new type of crystals. Ca/P ratio of enamel was found to be higher than that of teeth, this result seems to be true since the inorganic constituents of enamel are higher than that of dentine that form the main bulk of tooth [15, 16]. The presence of these elements in teeth samples indicating their incorporation through out the tooth layers during the pre-eruptive period of tooth development, on the other hand their presence in enamel may give an indication that there may be a continues incorporation of these elements in the outer enamel surface during the demineralization and remineralization processes that occurs in the post-eruptive periods. The presence of these trace elements in both teeth and enamel samples give us an idea that these elements present in our environment; as they present in foods as (meats, potatoes, cheeses, whole-grain breads and cereals, fresh fruits and vegetables, chicken, eggs, milk, nuts, dried beans and peas). These elements could also be found in water that used for drinking or cooking foods and in air as pollutant as for Cr VI that presents in air due to erosion of chromium-containing rocks and nickel that presents in cigarettes [17, 18, 19] that may inhale by those group as passive smokers.

Although statistically not significant, inverse correlations were recorded between caries-experience (DMFS) and major elements (Ca and P) in tooth sample, this could indicate the important role of these elements in mineralization process of teeth. The same results were seen for enamel, but with statistically significant correlation between P ions and DMFS. From all of the trace elements studied only Cr ions showed negative correlations with DMFS in both tooth and enamel samples, so it may have a role in improving resistance of teeth against caries; however these correlations were statistically not significant. For the other trace elements positive correlations were recorded with caries-experience (DMFS) in tooth and enamel. Although they were statistically not significant, except for Ni in teeth and Al in enamel, these positive correlations may indicate that these elements affect composition and crystallity of dental hard tissue in a way favoring an increase in dental caries. Regarding grads of lesion severity, most of elements showed weak and statistically not significant correlations, with variation in direction of these correlations, except Al ions which recorded positive and statistically significant correlation with D_3 in teeth samples and with D_1 in enamel samples, indicating that this ion may have a role in both initiation and progression of dental caries. The impact of major and trace elements on dental caries seems to be much more in enamel compared to the whole tooth, as results recorded a value of R^2 equal to 0.569 in enamel compared to only 0.320 in tooth, indicating that 56.9 % of changes occurred in DMFS were explained by inorganic composition of enamel, while the inorganic composition of the whole teeth explain only 32% of changes occurred in dental caries. This result gives an idea about the important role of composition and crystallity of enamel in the initiation of caries.

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Table 1: Caries – experience of permanent teeth (D_{1-4}MFS) among patients.

Fractions	Mean ± SD
DS	4.44 ± 2.48
MS	1.60 ± 2.78
FS	2.60 ± 2.60
DMFS	8.64 ± 4.06
D_1	0.84 ± 0.68
D_2	1.76 ± 0.87
D_3	1.20 ± 0.95
D_4	0.64 ± 1.11

Table 2: Concentration of elements in teeth and enamel samples (Mean ±SD) with statistical differences between teeth and enamel samples

Elements		Tooth	Enamel	t- value	Probability
		Mean ± SD	Mean ± SD		
Major elements in % of dry weight	Ca	21.56 ± 1.34	19.59 ± 1.32	5.215*	0.000
	P	11.90 ± 1.17	10.31 ± 2.00	4.946*	0.000
	Ca/P	1.82 ± 0.19	1.91 ± 0.23	- 1.527	0.133
Trace elements in ppm	Fe	8.40 ± 2.99	6.20 ± 2.24	2.936*	0.005
	Ni	12.47 ± 1.93	8.77 ± 1.26	7.984*	0.000
	Al	63.76 ± 22.56	25.60 ± 11.2	7.573*	0.000
	Cr	0.29 ± 0.03	0.17 ± 0.02	14.503*	0.000

Table 3: Correlation coefficients between elements in teeth and caries- experience

Elements		D_1		D_2		D_3		D_4		DS		FS		DMFS	
		R	P	R	P	r	P	r	P	R	P	r	P	r	P
Major	Ca	0.09	0.67	- 0.10	0.63	- 0.08	0.69	0.09	0.66	0.00	0.99	- 0.03	0.88	- 0.09	0.64
	P	- 0.24	0.23	- 0.09	0.64	0.07	0.74	0.22	0.28	0.02	0.91	- 0.19	0.36	- 0.29	0.15
	Ca/ P	0.29	0.14	0.05	0.79	- 0.88	0.67	- 0.16	0.41	0.01	0.96	0.16	0.44	0.24	0.23
Trace	Fe	0.16	0.43	- 0.09	0.65	- 0.16	0.43	- 0.03	0.88	- 0.06	0.76	0.05	0.78	0.05	0.80
	Al	0.25	0.21	0.06	0.74	0.46**	0.01	0.02	0.90	0.28	0.16	0.23	0.25	0.28	0.16
	Ni	0.02	0.91	0.05	0.80	0.09	0.64	0.25	0.22	0.17	0.40	0.22	0.29	0.40*	0.05
	Cr	0.02	0.89	- 0.02	0.89	0.32	0.11	0.03	0.85	0.14	0.50	- 0.09	0.65	- 0.07	0.73

Table 4: Correlation coefficients between elements in enamel and caries- experience

Elements		D_1		D_2		D_3		D_4		DS		FS		DMFS	
		r	P	R	P	r	P	R	P	R	P	r	P	r	P
Major	Ca	0.10	0.63	0.33	0.10	- 0.12	0.53	0.24	0.23	0.20	0.31	- 0.32	0.11	- 0.29	0.15
	P	- 0.16	0.43	- 0.08	0.68	0.01	0.94	0.18	0.37	0.01	0.95	- 0.28	0.17	- 0.4*	0.05
	Ca/P	0.26	0.19	0.23	0.26	- 0.06	0.76	- 0.05	0.81	0.11	0.57	0.09	0.65	0.13	0.53
Trace	Fe	0.07	0.72	0.08	0.69	0.31	0.12	0.25	0.21	0.28	0.16	- 0.09	0.63	0.20	0.31
	Al	0.44**	0.01	- 0.01	0.96	0.15	0.44	0.15	0.46	0.24	0.23	0.17	0.39	0.56**	0.003
	Ni	0.30	0.14	- 0.02	0.92	- 0.03	0.86	0.10	0.62	0.10	0.60	- 0.12	0.55	0.14	0.48
	Cr	0.29	0.14	0.15	0.46	0.11	0.59	0.10	0.62	0.22	0.27	- 0.01	0.63	- 0.15	0.45

Table 5: Multiple linear regressions (MLR) between elements in teeth and DMFS

Elements		B (Slope)	Std. Error	Beta	t	P- Value
Major	Ca	- 4.214	3.292	-1.393	- 1.280	0.218
	P	6.946	6.041	2.004	1.150	0.266
	Ca/P	53.571	41.087	2.544	1.304	0.210
Trace	Fe	0.106	0.285	0.078	0.371	0.715
	Al	0.022	0.042	0.120	0.510	0.617
	Ni	0.583	0.485	0.278	1.201	0.242
	Cr	15.955	31.449	0.122	0.507	0.618

R= 0.565 **R^2= 0.320**

Table 6: Multiple linear regressions (MLR) between elements in enamel and DMFS

Elements		B (Slope)	Std. Error	Beta	t	P- Value
Major	Ca	0.680	1.418	0.223	0.480	0.638
	P	- 4.342	2.852	- 1.174	-1.522	0.146
	Ca/P	- 18.294	14.968	- 1.034	-1.222	0.238
Trace	Fe	0.012	0.371	0.007	0.033	0.974
	Al	0.197	0.060	0.545	3.276	0.004
	Ni	0.464	0.597	0.145	0.777	0.448
	Cr	-7.337	31.591	- 0.043	- 0.232	0.819

R= 0.754 **R^2= 0.569**