

# RELATIONSHIP BETWEEN Ca, Cl, K, Mg, Mn, Na, P, AND Sr CONTENTS IN THE INTACT CROWNS OF HUMAN PERMANENT TEETH INVESTIGATED BY NEUTRON ACTIVATION ANALYSIS

V. Zaichick<sup>1</sup>, S. Zaichick<sup>1,2</sup>

<sup>1</sup> *Medical Radiological Research Centre, Korolyev St., 4, Obninsk, 249036, Russia, e-mail: [vezai@obninsk.com](mailto:vezai@obninsk.com)*

<sup>2</sup> *Current address: University of Illinois College of Medicine Chicago, IL 60612, USA*

## Introduction

To use chemical element composition as estimation of bone and teeth health in stomatological, geographical, environmental and occupational medicine, paleoanthropology, and other directions, it is necessary to know normal levels and age- and gender-related changes of chemical element contents and their ratios.<sup>[1-22]</sup>

In our previous studies it was shown that samples are contaminated by trace elements from stainless steel tools during the sample preparation.<sup>23</sup> There is evidence that some chemical elements are lost if tooth samples are treated with solvents in order to remove the organic matrix, and are then ashed and acid digested.<sup>24,25</sup>

This work had three aims. The first was to determine the Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the intact crowns of human permanent teeth by instrumental neutron activation analysis with high resolution spectrometry of short-lived radionuclides (INAA-SLR) and to calculate some statistical parameters of Cl/Ca, K/Ca, Mg/Ca, Mn/Ca, Na/Ca, P/Ca, Sr/Ca, Ca/P, Cl/P, K/P, Mg/P, Mn/P, Na/P, Sr/P, Ca/Mg, Cl/Mg, Mn/Mg, Na/Mg, P/Mg, Sr/Mg, Ca/Cl, K/Cl, Mg/Cl, Mn/Cl, Na/Cl, P/Cl, Sr/Cl, Ca/K, Cl/K, Mg/K, Mn/K, Na/K, P/K, Sr/K, Ca/Na, Cl/Na, K/Na, Mg/Na, Mn/Na, P/Na, and Sr/Na mass fraction ratios. The second aim was to evaluate the effect of age and gender on mean values of ratios of chemical element mass fractions. The third aim was to estimate the inter correlations between Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in intact crowns of human permanent teeth.

All studies were approved by the Ethical Committee of the Medical Radiological Research Center, Obninsk.

## Experimental part

Tooth crown samples were obtained at postmortems from intact cadavers (38 female and 46 male, 15–58 years old) within 24 h of death. Samples were freeze dried until constant mass was obtained. All subjects died mainly due to trauma. A titanium tool was used to cut and to scrub samples as well as to cut teeth crowns. The samples weighing about 100 mg for INAA-SLR were sealed separately in thin polyethylene film washed beforehand with acetone and rectified alcohol. The sealed samples were placed in labeled polyethylene ampoules.

To determine contents of the elements by comparison with a known standard, biological synthetic standards (BSS) prepared from phenol–formaldehyde resins and chemically pure compounds were used.<sup>[26]</sup> Ten certified reference materials (CRM) IAEA H-5 (Animal Bone) and standard reference materials (SRM) NIST 1486 (Bone Meal) sub-samples weighing about

50–100 mg were analyzed in the same conditions as teeth samples to estimate the precision and accuracy of results.

The mass fractions of Ca, Cl, K, Mg, Mn, Na, P, and Sr were determined by INAA-SLR using a horizontal channel equipped with the pneumatic rabbit system of the WWR-c research nuclear reactor. The information of used nuclear reactions, radionuclides, gamma-energies, neutron flux, spectrometer and other details of the analysis including the quality control of results were reported by us before.<sup>[6, 26]</sup>

A dedicated computer program of NAA mode optimization was used.<sup>[27]</sup> Using the Microsoft Office Excel programs, the summary of statistics were calculated for different ratios of chemical element mass fractions. The reliability of difference in the results between two age groups and between females and males was evaluated by Student's *t*-test. The Pearson's correlation analysis was used to identify relationships between elements.

## Results and discussion

Tables 1-3 represent certain statistical parameters (arithmetic mean, standard deviation, standard error of mean, minimal and maximal values, median, percentiles with 0.025 and 0.975 levels) of 42 different ratios of Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the teeth crowns of males and females, and of both females and males, taken together.

The obtained values for Ca/P ratio, as shown in Tables 1-3, agree well with median of means cited by other researchers for the teeth enamel.<sup>[28, 29]</sup> No published data referring to ratios of Ca/P or other chemical element mass fractions in human teeth crowns was found.

To estimate the effect of age on the chemical element ratios in teeth crowns we examined two age groups: one comprised a younger group with ages from 15 to 35 years and the other comprised older people with ages ranging from 36 to 55 years (Table 4). In female teeth crowns it was found a significant age-related decrease of the Sr/Ca, Sr/P, Sr/Na, and Cl/Na ratios accompanied an increase of the K/Cl, Na/Cl, and P/Cl ratios. In male teeth crowns the Ca/Mg, Cl/Mg, K/Mg, P/Mg, and K/Na ratios decrease with age.

We used the entire data set for both females and males taken separately, seeking to detect the presence of gender-related differences (see Table 5). A statistically significant gender-related difference was only detected for Mg/K, Mn/K, and Mg/Na mass fractions ratios. In male teeth crowns these ratios are higher than those in female. No published data referring to age- and gender-related differences of ratios of chemical element mass fractions in human teeth crowns were found.

Table 6 depicts the inter-correlation calculations including all chemical elements identified by us. For example, the positive inter-correlations of Ca mass fractions with P ( $p < 0.001$ ), Cl ( $p < 0.01$ ), and Na ( $p < 0.05$ ) mass fractions were found in teeth crowns. If some correlations between the elements were predictable (e.g., Ca–P), the interpretation of other observed relationships requires further study for a more complete understanding

## Conclusions

All the deceased were citizens of Obninsk, a small city of non-industrial region near Moscow. None of those who died a sudden death had suffered from any systematic or chronic disorders before. Thus, our data for element mass fraction ratios in the intact teeth crowns may serve as indicative normal values for residents of the Central European region of Russia.

**Table 1.** Some statistical parameters of 42 different ratios of Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the intact permanent teeth crowns of males

Ratio	M	SD	SEM	Min	Max	Med	P0.025	P0.975
(Cl/Ca) $\times 10^3$	8.22	3.05	0.47	3.02	14.1	8.90	3.81	14.0
(K/Ca) $\times 10^3$	2.13	1.53	0.25	0.433	8.24	1.97	0.485	6.55
(Mg/Ca) $\times 10^2$	1.53	0.64	0.10	0.601	3.40	1.47	0.662	2.86
(Mn/Ca) $\times 10^6$	10.4	8.3	1.3	0.587	32.3	7.38	2.09	29.8
(Na/Ca) $\times 10^2$	1.78	0.37	0.06	0.861	3.17	1.71	1.23	2.73
P/Ca	0.509	0.065	0.010	0.338	0.715	0.499	0.359	0.598
(Sr/Ca) $\times 10^3$	0.82	0.69	0.11	0.0860	2.71	0.513	0.100	2.38
Ca/P	2.00	0.28	0.04	1.40	2.96	2.01	1.67	2.79
(Cl/P) $\times 10^2$	1.63	0.59	0.09	0.506	2.87	1.64	0.726	2.69
(K/P) $\times 10^2$	0.413	0.289	0.050	0.0691	1.65	0.377	0.0924	1.12
(Mg/P) $\times 10^2$	3.11	1.42	0.22	1.02	7.18	2.84	1.11	5.71
(Mn/P) $\times 10^6$	20.2	15.9	2.5	1.18	65.1	15.6	4.07	59.7
(Na/P) $\times 10^2$	3.57	0.95	0.15	1.81	6.85	3.40	2.17	5.85
(Sr/P) $\times 10^3$	1.61	1.29	0.21	0.144	4.62	1.12	0.176	4.55
Ca/Mg	78.0	35.2	5.4	29.4	166	67.9	35.0	151
Cl/Mg	0.664	0.436	0.070	0.121	2.05	0.600	0.146	1.95
K/Mg	0.184	0.190	0.030	0.0226	0.969	0.103	0.0317	0.660
(Mn/Mg) $\times 10^4$	8.81	8.53	1.32	0.316	35.8	6.19	0.652	28.6
Na/Mg	1.37	0.67	0.10	0.454	3.55	1.25	0.631	2.88
P/Mg	40.5	21.1	3.3	13.9	97.6	35.2	17.5	90.1
Sr/Mg	0.072	0.085	0.010	0.0067	0.451	0.0352	0.0073	0.204
Ca/Cl	143.2	63.9	9.9	71.1	331	112	71.4	263
K/Cl	0.321	0.348	0.060	0.0493	2.12	0.248	0.0502	0.856
Mg/Cl	2.32	1.74	0.27	0.488	8.29	1.67	0.515	6.82
(Mn/Cl) $\times 10^4$	14.4	15.0	2.3	1.23	78.4	10.2	1.75	57.5
Na/Cl	2.58	1.45	0.22	1.25	7.77	1.87	1.29	6.34
P/Cl	72.5	34.3	5.3	34.8	198	61.1	37.1	138
Sr/Cl	0.106	0.082	0.010	0.0095	0.337	0.0759	0.0194	0.277
Ca/K	738	558	91	121	2309	507	153	2063
Cl/K	5.80	4.91	0.80	0.471	20.3	4.03	1.26	19.9
Mg/K	11.1	9.1	1.5	1.03	44.2	9.67	1.53	31.8
(Mn/K) $\times 10^4$	60.6	46.8	7.6	5.07	195	45.1	7.80	175
Na/K	12.1	7.9	1.3	2.09	33.1	10.0	3.54	32.3
P/K	379	302	49	60.7	1447	265	90.7	1089
Sr/K	0.53	0.80	0.13	0.0366	4.82	0.316	0.0733	1.84
Ca/Na	58.5	12.7	2.0	31.5	116	58.5	36.6	81.1
Cl/Na	0.479	0.185	0.030	0.129	0.801	0.535	0.151	0.774
K/Na	0.120	0.083	0.010	0.0302	0.478	0.0996	0.0309	0.289
Mg/Na	0.883	0.381	0.060	0.282	2.20	0.802	0.347	1.59
(Mn/Na) $\times 10^4$	5.99	4.93	0.76	0.351	20.2	4.46	0.807	17.3
P/Na	29.8	7.4	1.1	14.6	55.3	29.4	17.1	46.1
Sr/Na	0.476	0.427	0.070	0.0545	1.76	0.290	0.0642	1.47

M - arithmetic mean; SD - standard deviation; SEM - standard error of mean; Min - minimum value; Max - maximum value; Med - median; Per. 0.025 - percentile with 0.025 level; Per. 0.975 - percentile with 0.975 level

**Table 2.** Some statistical parameters of 42 different ratios of Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the intact permanent teeth crowns of females

Ratio	M	SD	SEM	Min	Max	Med	P0.025	P0.975
(Cl/Ca)×10 <sup>3</sup>	8.41	4.05	0.72	2.37	17.3	8.03	2.71	17.0
(K/Ca) ×10 <sup>3</sup>	2.84	2.67	0.47	0.351	15.2	2.27	0.788	10.0
(Mg/Ca) ×10 <sup>2</sup>	1.29	0.65	0.11	0.127	2.80	1.16	0.510	2.77
(Mn/Ca) ×10 <sup>6</sup>	7.68	5.98	1.10	0.273	30.4	7.96	1.04	19.8
(Na/Ca) ×10 <sup>2</sup>	1.84	0.35	0.06	1.08	2.68	1.75	1.32	2.55
P/Ca	0.527	0.075	0.010	0.377	0.714	0.522	0.402	0.704
(Sr/Ca) ×10 <sup>3</sup>	0.97	0.59	0.10	0.342	3.11	0.819	0.356	2.17
Ca/P	1.93	0.28	0.05	1.40	2.65	1.92	1.42	2.49
(Cl/P) ×10 <sup>2</sup>	1.57	0.72	0.13	0.581	3.11	1.44	0.599	3.09
(K/P) ×10 <sup>2</sup>	0.502	0.397	0.070	0.0719	2.13	0.433	0.0996	1.73
(Mg/P) ×10 <sup>2</sup>	2.47	1.32	0.23	0.239	6.17	2.23	0.946	5.43
(Mn/P) ×10 <sup>6</sup>	14.2	10.9	1.9	0.615	56.1	15.5	1.28	35.4
(Na/P) ×10 <sup>2</sup>	3.48	0.85	0.15	1.43	5.55	3.34	2.40	5.46
(Sr/P) ×10 <sup>3</sup>	1.88	1.14	0.20	0.650	5.73	1.53	0.709	4.69
Ca/Mg	111	127	22	35,7	790	86.3	36.1	290
Cl/Mg	0.94	1.04	0.18	0.121	5.95	0.717	0.153	3.27
K/Mg	0.316	0.427	0.070	0.0348	1.87	0.182	0.0495	1.71
(Mn/Mg) ×10 <sup>4</sup>	8.49	12.5	2.2	0.192	70.8	5.88	0.687	32.7
Na/Mg	1.89	1.72	0.30	0.656	10.9	1.51	0.749	4.37
P/Mg	59	67	11	16.2	418	44.9	18.5	148
Sr/Mg	0.098	0.076	0.010	0.0137	0.393	0.080	0.0224	0.254
Ca/Cl	156	93	17	58.0	421	125	58.9	370
K/Cl	0.379	0.312	0.060	0.0829	1.48	0.287	0.104	1.14
Mg/Cl	2.14	1.99	0.35	0.168	8.26	1.39	0.342	6.63
(Mn/Cl) ×10 <sup>4</sup>	10.4	8.5	1.5	0.199	34.3	10.5	0.905	31.9
Na/Cl	2.86	1.83	0.32	0.952	7.44	2.14	0.995	6.87
P/Cl	79.1	39.5	6.9	32.1	172	69.4	32.4	167
Sr/Cl	0.149	0.120	0.020	0.0374	0.510	0.126	0.0408	0.505
Ca/K	561	484	86	65.7	2847	441	106	1487
Cl/K	4.28	2.83	0.50	0.675	12.1	3.49	0.893	9.72
Mg/K	7.3	6.1	1.1	0.535	28.7	5.50	0.586	20.8
(Mn/K) ×10 <sup>4</sup>	34.5	19.8	3.6	9.79	87.1	33.9	9.95	78.4
Na/K	10.3	9.2	1.6	1.30	56.1	7.78	2.23	26.3
P/K	305	255	44	46.9	1391	231	58.4	1029
Sr/K	0.558	0.542	0.090	0.0438	2.76	0.376	0.0566	2.05
Ca/Na	56.2	11.2	2.0	37.3	92.9	57.3	39.3	76.4
Cl/Na	0.498	0.276	0.050	0.134	1.05	0.468	0.146	1.00
K/Na	0.150	0.131	0.020	0.0178	0.767	0.129	0.0460	0.479
Mg/Na	0.709	0.317	0.050	0.0916	1.52	0.664	0.293	1.34
(Mn/Na) ×10 <sup>4</sup>	4.20	3.41	0.60	0.165	17.4	3.89	0.548	12.1
P/Na	31	9.0	1.5	18.0	69.9	30.0	18.3	43.8
Sr/Na	0.566	0.359	0.060	0.181	1.78	0.437	0.204	1.46

M - arithmetic mean; SD – standard deviation; SEM – standard error of mean; Min – minimum value; Max – maximum value; Med – median; Per. 0.025 – percentile with 0.025 level; Per. 0.975 – percentile with 0.975 level

**Table 3.** Some statistical parameters of 42 different ratios of Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the intact permanent teeth crowns of males and females, taken together

Ratio	M	SD	SEM	Min	Max	Med	P0.025	P0.975
(Cl/Ca)×10 <sup>3</sup>	8.30	3.49	0.41	2.37	17.3	8.46	2.93	15.0
(K/Ca) ×10 <sup>3</sup>	2.45	2.14	0.26	0.351	15.2	2.09	0.474	8.31
(Mg/Ca) ×10 <sup>2</sup>	1.43	0.65	0.08	0.127	3.40	1.30	0.605	2.81
(Mn/Ca) ×10 <sup>6</sup>	9.22	7.48	0.90	0.273	32.3	7.71	1.16	30.0
(Na/Ca) ×10 <sup>2</sup>	1.81	0.36	0.04	0.861	3.17	1.73	1.21	2.69
P/Ca	0.517	0.070	0.010	0.338	0.715	0.518	0.374	0.704
(Sr/Ca) ×10 <sup>3</sup>	0.892	0.646	0.080	0.0860	3.11	0.703	0.111	2.44
Ca/P	1.97	0.28	0.03	1.38	2.96	1.93	1.42	2.68
(Cl/P) ×10 <sup>2</sup>	1.60	0.65	0.07	0.506	3.11	1.54	0.600	3.04
(K/P) ×10 <sup>2</sup>	0.454	0.344	0.040	0.0691	2.13	0.402	0.0887	1.63
(Mg/P) ×10 <sup>2</sup>	2.82	1.40	0.16	0.239	7.18	2.58	1.09	5.78
(Mn/P) ×10 <sup>6</sup>	17.6	14.2	1.7	0.615	65.1	15.5	1.42	56.7
(Na/P) ×10 <sup>2</sup>	3.53	0.90	0.10	1.43	6.85	3.40	2.12	5.80
(Sr/P) ×10 <sup>3</sup>	1.73	1.22	0.14	0.144	5.73	1.40	0.220	4.56
Ca/Mg	93	89	10	29.4	790	76.9	35.6	165
Cl/Mg	0.787	0.768	0.090	0.121	5.95	0.630	0.142	2.13
K/Mg	0.245	0.327	0.040	0.0226	1.87	0.145	0.0342	1.30
(Mn/Mg) ×10 <sup>4</sup>	8.7	10.3	1.2	0.192	70.8	6.04	0.585	29.9
Na/Mg	1.60	1.27	0.15	0.454	10.9	1.34	0.653	3.05
P/Mg	48.8	47.8	5.5	13.9	418	38.7	17.3	92.0
Sr/Mg	0.084	0.081	0.010	0.0067	0.451	0.0611	0.0089	0.258
Ca/Cl	149	78	9	58.0	421	118	66.8	342
K/Cl	0.348	0.331	0.040	0.0493	2.12	0.265	0.0513	1.17
Mg/Cl	2.24	1.84	0.21	0.168	8.29	1.59	0.472	7.06
(Mn/Cl) ×10 <sup>4</sup>	12.7	12.7	1.5	0.199	78.4	10.3	1.21	40.6
Na/Cl	2.70	1.63	0.19	0.952	7.77	2.03	1.02	6.83
P/Cl	75.4	36.6	4.2	32.1	198	64.9	32.9	167
Sr/Cl	0.125	0.103	0.010	0.0095	0.510	0.0945	0.0207	0.380
Ca/K	657	529	63	65.7	2847	479	120	2116
Cl/K	5.11	4.13	0.49	0.471	20.3	3.78	0.879	19.5
Mg/K	9.34	8.01	0.95	0.535	44.2	6.89	0.790	29.2
(Mn/K) ×10 <sup>4</sup>	48.9	39.2	4.7	5.07	195	38.0	8.35	164
Na/K	11.3	8.5	1.0	1.30	56.1	8.56	2.37	32.5
P/K	345	282	33	46.9	1447	249	61.2	1143
Sr/K	0.545	0.685	0.080	0.0366	4.82	0.358	0.0553	2.11
Ca/Na	57.5	12.0	1.4	31.5	116	58.0	37.2	82.9
Cl/Na	0.487	0.228	0.030	0.129	1.05	0.494	0.147	0.983
K/Na	0.134	0.108	0.010	0.0178	0.767	0.117	0.0308	0.424
Mg/Na	0.805	0.362	0.040	0.0916	2.20	0.749	0.329	1.53
(Mn/Na) ×10 <sup>4</sup>	5.22	4.40	0.51	0.165	20.2	4.22	0.605	17.4
P/Na	30.1	8.1	0.9	14.6	69.9	29.4	17.2	47.3
Sr/Na	0.518	0.397	0.050	0.0545	1.78	0.395	0.0784	1.52

M - arithmetic mean; SD – standard deviation; SEM – standard error of mean; Min – minimum value; Max – maximum value; Med – median; Per. 0.025 – percentile with 0.025 level; Per. 0.975 – percentile with 0.975 level

**Table 4.** Effect of age on mean values (M±SEM) of ratios of chemical element mass fractions in the intact permanent teeth crowns (Student's *t*-test)

Ratio	Females			Males		
	15-35 year	36-55 year	<i>p</i>	15-35 year	36-55 year	<i>p</i>
(Cl/Ca)×10 <sup>3</sup>	9.79±1.06	7.33±0.92	N.S.	8.87±0.82	7.73±0.54	N.S.
(K/Ca) ×10 <sup>3</sup>	2.29±0.22	3.27±0.82	N.S.	2.63±0.43	1.76±0.28	N.S.
(Mg/Ca) ×10 <sup>2</sup>	1.22±0.11	1.35±0.18	N.S.	1.36±0.17	1.66±0.12	N.S.
(Mn/Ca) ×10 <sup>6</sup>	9.1±2.0	6.5±1.1	N.S.	9.4±1.7	11.1±1.9	N.S.
(Na/Ca) ×10 <sup>2</sup>	1.74±0.07	1.92±0.09	N.S.	1.76±0.06	1.80±0.09	N.S.
P/Ca	0.519±0.010	0.534±0.021	N.S.	0.525±0.020	0.497±0.009	N.S.
(Sr/Ca) ×10 <sup>3</sup>	1.28±0.19	0.750±0.075	≤0.05	1.00±0.18	0.68±0.14	N.S.
Ca/P	1.95±0.06	1.92±0.07	N.S.	1.96±0.09	2.03±0.04	N.S.
(Cl/P) ×10 <sup>2</sup>	1.82±0.17	1.37±0.17	N.S.	1.71±0.15	1.56±0.11	N.S.
(K/P) ×10 <sup>2</sup>	0.41±0.04	0.58±0.12	N.S.	0.51±0.09	0.34±0.05	N.S.
(Mg/P) ×10 <sup>2</sup>	2.31±0.21	2.61±0.37	N.S.	2.71±0.36	3.40±0.26	N.S.
(Mn/P) ×10 <sup>6</sup>	16.3±3.6	12.4±1.8	N.S.	18.1±3.3	21.8±3.5	N.S.
(Na/P) ×10 <sup>2</sup>	3.28±0.24	3.65±0.17	N.S.	3.49±0.25	3.62±0.18	N.S.
(Sr/P) ×10 <sup>3</sup>	2.43±0.35	1.44±0.16	≤0.05	1.91±0.32	1.37±0.27	N.S.
Ca/Mg	90.3±7.7	127±38	N.S.	92.2±9.9	67.4±5.1	≤0.05
Cl/Mg	0.89±0.11	0.99±0.32	N.S.	0.85±0.13	0.53±0.05	≤0.05
K/Mg	0.20±0.03	0.41±0.13	N.S.	0.256±0.042	0.132±0.041	≤0.05
(Mn/Mg) ×10 <sup>4</sup>	7.5±1.6	9.4±4.0	N.S.	9.8±1.9	8.1±1.8	N.S.
Na/Mg	1.51±0.13	2.19±0.51	N.S.	1.59±0.17	1.21±0.12	N.S.
P/Mg	48±4	68±20	N.S.	49.1±5.9	34.0±3.1	≤0.05
Sr/Mg	0.115±0.020	0.084±0.019	N.S.	0.103±0.026	0.047±0.011	N.S.
Ca/Cl	123±17	182±25	N.S.	134±15	150±13	N.S.
K/Cl	0.260±0.040	0.484±0.091	≤0.05	0.339±0.052	0.309±0.091	N.S.
Mg/Cl	1.58±0.36	2.60±0.55	N.S.	1.98±0.42	2.57±0.35	N.S.
(Mn/Cl) ×10 <sup>4</sup>	9.8±2.2	11.0±2.2	N.S.	11.7±2.1	16.3±3.7	N.S.
Na/Cl	2.16±0.35	3.45±0.47	≤0.05	2.35±0.26	2.75±0.34	N.S.
P/Cl	63±7	92±10	≤0.05	69.8±7.9	74.5±7.2	N.S.
Sr/Cl	0.160±0.030	0.139±0.028	N.S.	0.115±0.017	0.099±0.020	N.S.
Ca/K	507±59	603±146	N.S.	588±138	846±117	N.S.
Cl/K	5.23±0.75	3.46±0.62	N.S.	4.8±1.1	6.5±1.1	N.S.
Mg/K	6.7±1.0	7.9±1.8	N.S.	8.5±2.8	13.0±1.5	N.S.
(Mn/K) ×10 <sup>4</sup>	37.3±5.9	31.9±4.1	N.S.	45±7	72±12	N.S.
Na/K	9.2±1.1	11.2±2.8	N.S.	9.8±2.1	13.8±1.5	N.S.
P/K	304±53	306±70	N.S.	327±89	416±55	N.S.
Sr/K	0.66±0.11	0.47±0.15	N.S.	0.44±0.08	0.60±0.23	N.S.
Ca/Na	58.6±2.2	54.4±3.0	N.S.	57.9±2.0	58.9±3.1	N.S.
Cl/Na	0.610±0.070	0.404±0.059	≤0.05	0.510±0.048	0.455±0.035	N.S.
K/Na	0.130±0.010	0.166±0.040	N.S.	0.155±0.025	0.094±0.012	≤0.05
Mg/Na	0.726±0.060	0.696±0.088	N.S.	0.771±0.087	0.966±0.077	N.S.
(Mn/Na) ×10 <sup>4</sup>	5.1±1.1	3.45±0.51	N.S.	5.6±1.1	6.3±1.1	N.S.
P/Na	33.2±3.0	28.5±1.3	N.S.	30.7±1.8	29.1±1.5	N.S.
Sr/Na	0.79±0.11	0.39±0.04	≤0.01	0.58±0.11	0.39±0.08	N.S.

M – Arithmetical mean, SEM – standard error of mean, N.S. – non significant (*p*>0.05)

**Table 5.** Effect of gender on mean values (M±SEM) of ratios of chemical element mass fractions in the intact permanent teeth crowns (Student's *t*-test)

Ratio	Males	Females	<i>p</i>
(Cl/Ca)×10 <sup>3</sup>	8.22±0.47	8.41±0.72	N.S.
(K/Ca) ×10 <sup>3</sup>	2.13±0.25	2.84±0.47	N.S.
(Mg/Ca) ×10 <sup>2</sup>	1.53±0.10	1.29±0.11	N.S.
(Mn/Ca) ×10 <sup>6</sup>	10.4±1.3	7.7±1.1	N.S.
(Na/Ca) ×10 <sup>2</sup>	1.78±0.06	1.84±0.06	N.S.
P/Ca	0.509±0.010	0.527±0.010	N.S.
(Sr/Ca) ×10 <sup>3</sup>	0.82±0.11	0.97±0.10	N.S.
Ca/P	2.00±0.04	1.93±0.05	N.S.
(Cl/P) ×10 <sup>2</sup>	1.63±0.09	1.57±0.13	N.S.
(K/P) ×10 <sup>2</sup>	0.413±0.050	0.502±0.070	N.S.
(Mg/P) ×10 <sup>2</sup>	3.11±0.22	2.47±0.23	N.S.
(Mn/P) ×10 <sup>6</sup>	20.2±2.5	14.2±1.9	N.S.
(Na/P) ×10 <sup>2</sup>	3.57±0.15	3.48±0.15	N.S.
(Sr/P) ×10 <sup>3</sup>	1.61±0.21	1.88±0.20	N.S.
Ca/Mg	78.0±5.4	111±22	N.S.
Cl/Mg	0.66±0.07	0.94±0.18	N.S.
K/Mg	0.184±0.030	0.316±0.070	N.S.
(Mn/Mg) ×10 <sup>4</sup>	8.81±1.32	8.49±2.2	N.S.
Na/Mg	1.37±0.10	1.89±0.30	N.S.
P/Mg	40.5±3.3	59±11	N.S.
Sr/Mg	0.072±0.010	0.098±0.010	N.S.
Ca/Cl	143.2±9.9	156±17	N.S.
K/Cl	0.321±0.060	0.379±0.060	N.S.
Mg/Cl	2.32±0.27	2.14±0.35	N.S.
(Mn/Cl) ×10 <sup>4</sup>	14.4±2.3	10.4±1.5	N.S.
Na/Cl	2.58±0.22	2.86±0.32	N.S.
P/Cl	72.5±5.3	79.1±6.9	N.S.
Sr/Cl	0.106±0.010	0.149±0.020	N.S.
Ca/K	738±91	561±86	N.S.
Cl/K	5.80±0.80	4.28±0.50	N.S.
Mg/K	11.1±1.5	7.3±1.1	≤0.05
(Mn/K) ×10 <sup>4</sup>	60.6±7.6	34.5±3.6	≤0.01
Na/K	12.1±1.3	10.3±1.6	N.S.
P/K	379±49	305±44	N.S.
Sr/K	0.53±0.13	0.56±0.09	N.S.
Ca/Na	58.5±2.0	56.2±2.0	N.S.
Cl/Na	0.479±0.030	0.498±0.050	N.S.
K/Na	0.120±0.010	0.150±0.020	N.S.
Mg/Na	0.883±0.060	0.709±0.050	≤0.05
(Mn/Na) ×10 <sup>4</sup>	5.99±0.76	4.20±0.60	N.S.
P/Na	29.8±1.1	31± 1.5	N.S.
Sr/Na	0.476±0.070	0.566±0.060	N.S.

M – Arithmetical mean, SEM – standard error of mean, N.S. – non significant

**Table 6.** Inter-correlations ( $r$  – coefficient of correlation) of Ca, Cl, K, Mg, Mn, Na, P, and Sr mass fractions in the intact crowns of human permanent teeth

Element	Ca	Cl	K	Mg	Mn	Na	P	Sr
Ca	xxxx	0.348 <sup>b</sup>	0.034	-0.205	0.134	0.244 <sup>a</sup>	0.668 <sup>c</sup>	0.033
Cl	0.348	xxxx	0.140	-0.312 <sup>b</sup>	0.170	-0.020	0.428 <sup>c</sup>	0.246 <sup>a</sup>
K	0.034	0.140	xxxx	-0.215	0.423 <sup>c</sup>	0.253 <sup>a</sup>	0.254 <sup>a</sup>	0.123
Mg	-0.205	-0.312 <sup>b</sup>	-0.215	xxxx	-0.205	0.185	-0.275 <sup>a</sup>	-0.100
Mn	0.134	0.170	0.423 <sup>c</sup>	-0.205	xxxx	0.087	0.223 <sup>a</sup>	0.208
Na	0.244 <sup>a</sup>	-0.020	0.253 <sup>a</sup>	0.185	0.087	xxxx	0.160	-0.047
P	0.668 <sup>c</sup>	0.428 <sup>c</sup>	0.254 <sup>a</sup>	-0.275 <sup>a</sup>	0.223 <sup>a</sup>	0.160	xxxx	0.095
Sr	0.033	0.123	0.123	-0.100	0.208	-0.047	0.095	xxxx

Statistically significant difference: <sup>a</sup> -  $p \leq 0.05$ , <sup>b</sup> -  $p \leq 0.01$ , <sup>c</sup> -  $p \leq 0.001$ .

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