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Preliminary results of Sr/Ca ratio study of teeth samples by photoactivation analysis

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Abstract. In this paper, we have performed Photoactivation Analysis (PAA), a non-destructive method, which is used to determine elemental concentration of any sample. This paper presents the first use of this method in medical sciences in Turkey. The method was applied to the determination of Sr/Ca ratios in teeth. The collected teeth samples and standards (SrO and $CaCO_3$) have been irradiated for a fixed time interval with high energy photons. The photons were generated by a clinical linear accelerator (cLINAC). The photon end-point energy was 18 MeV. The energy and the time interval were sufficient to achieve good activation. Afterward, the samples and standards have been analysed with gamma spectroscopic analysis by using an HPGe detector system. By analysing many samples, a database of Sr/Ca ratios will be created at Nuclear Research and Application Center (NUBA). In this paper we present a small subset of the already analysed data as an example of our capabilities and goal. We hope to set an example for future studies.

1. Introduction

The interest in the lifestyles of ancient societies is increasing day by day. Among these studies, determination of nutrition models, the discovery of migration patterns, achieve the population structure, constructed of community way of life, the relationship between diseases and lifestyle, determination of individual growth and development through identification of environmental compliance strategy holds an important role. Especially, teeth provide more information to investigate the effects on humans of environmental factors, disease and nutrition. In order to avoid biological, environmental, and archaeological specimens' damage to the preservation of basic and trace elements and values that are available for non-destructive analysis is very important. There are alkaline earth metals present in the structure of teeth like Strontium (Sr), Calcium (Ca), Barium (Ba) and Magnesium (Mg) [1, 14]. Of these alkali metals, Sr/Ca ratio is very useful parameter. Sr/Ca ratio, determination of the effect of environmental food science and nutrition, breastfeeding offers focused on the biological importance of human health such as diagnosis and treatment process. The ratios of strontium (Sr) and calcium (Ca) elements which are found abundantly in teeth will have benefits in biological, archaeological and anthropological studies. This ratio having chemically similar, often used to understand the influence of the environment [2,13] such as previous life of dietary information [4,11,12], cutting applications milk [5,9], food and disease event. Besides, this study is expected to provide an insight on health issues like eating habits -therefore welfare levels- of people within different time frames, effects of breastfeeding, environmental influence on disease and nutritional status, determination of age-race, evaluation of teeth quality, and evaluation of treatment success of teeth recovery. Sr concentration was used to examine the dietary in prehistoric human populations. Also it is used to determine to rate of consumed meat and plants [6-8]. Method here, in order to support the calcium, mammalian digestive system provides discrimination to strontium [10]. In addition, Mammalian kidneys filter out the strontium faster than calcium from the body. Therefore, individuals who consume large amounts of meat is supposed to be have amounts of strontium in skeletons [8]. This discrimination against strontium (or calcium bio-treatment) has been proven in the High Sierras where full of carnivores, herbivores and plant in the natural food chain in a discrete ecosystem of the alpine foothills [3].

2. Material and Method

Teeth samples were collected from the patients of Akdeniz University Faculty of Dentistry. The collected samples and prepared standards (SrO and CaCO3) were irradiated for a specific period of time with a clinical linear accelerator (cLINAC) of 18 MeV bremsstrahlung energy to achieve photo-activation. The prepared calibration material was controlled with universally reference material (URM, table 1). Afterwards, the samples and standards are analyzed with gamma spectroscopic analysis method using an HPGe detector system and a database is formed.

The teeth samples and reference materials are prepared in the same geometry and then placed 56 cm away from the irradiation zone to perform irradiation (Fig. 1). The electrons obtained from electron gun, hit the tungsten target resulting in bremsstrahlung photons and are directed with primary collimators towards the flattening filter (Fig. 2). Wherein, the photon flux along the dotted line has the highest value in Fig. 2. Therefore, by using of a smoothing filter with a triangular geometry a spatial homogeneous photon flux distribution is achieved. After passing the ionization chamber used in dosimetry, photons eventually (Y and X aperture are fully open) form a 40x40 cm^2 square at 100 cm distance. The width of the field can be expanded or reduced by the diaphragm Y and X.

Fig. 1: Philips SLI-25 clinical linear electron accelerator of Elekta TM Synergy TM.

By making the necessary settings from the control room, it is possible to ensured same exposure to sample and reference. Over a course of two hours, samples are subjected to bremsstrahlung photons with sufficient energy (usually between 18 and 30 MeV) to induce photonuclear reactions. Both samples are assumed to be subjected to the same amount of photon flux during this process. A second assumption is that the isotopes in both of the analyzed samples are found in their natural abundance. Based on these assumptions and the model of activation analysis, the relative concentrations of the elements in the examined samples is calculated from equations (1) and (2) [9]:

$$c_s = F_{corr} \cdot \frac{c_{cal} \cdot m_{cal} \cdot P_s}{m_s \cdot P_{cal}} \cdot \frac{e^{-\lambda\left(t_{d_{cal}} - t_{d_s}\right)} - e^{-\lambda\left(t_{d_{cal}} - t_{d_s} \quad t_{c_{cal}} +\right)}}{1 - e^{-\lambda \cdot t_{c_s}}} \quad (1)$$

$$F_{corr} = \frac{(m_{Mon1Sm} + m_{Mon2Sm}) \cdot \left(\frac{I_{Mon1Cal} \cdot \lambda_{Mon}}{e^{-\lambda_{Mon} \cdot t_{dMon1Cal}} \cdot (1 - e^{-\lambda_{Mon} \cdot t_{cMon1cal}})} + \frac{I_{Mon2Cal} \cdot \lambda_{Mon}}{e^{-\lambda_{Mon} \cdot t_{dMon2Cal}} \cdot (1 - e^{-\lambda_{Mon} \cdot t_{cMon2Cal}})} \right)}{(m_{Mon1Cal} + m_{Mon2Cal}) \cdot \left(\frac{I_{Mon1Sm} \cdot \lambda_{Mon}}{e^{-\lambda_{Mon} \cdot t_{dMon1Sm}} \cdot (1 - e^{-\lambda_{Mon} \cdot t_{cMon1Sm}})} + \frac{I_{Mon2Sm} \cdot \lambda_{Mon}}{e^{-\lambda_{Mon} \cdot t_{dMon2Sm}} \cdot (1 - e^{-\lambda_{Mon} \cdot t_{cMon2Sm}})} \right)} \quad (2)$$

where c_{cal} is the concentration of the element under study in the calibration material, m_{cal}, m_s are the mass of calibration and sample, P_s , P_{cal} are the net peak integral of the analyses to be determined in the sample and calibration material, λ is the decay constant of the radionuclides (^{47}Ca, ^{87m}Sr) produced during photon activation, t_d, t_c are decay and counting period of the sample/calibration material, M_{mon} is the masses of the bremsstrahlung flux monitors, I_{mon} is the annihilation net peak integrals of the monitor spectra, λ_{mon} is the decay constant of the monitor radionuclide (^{64}Cu) produced during photon activation, t_{dMon}, t_{cMon} are decay and counting period of the monitors. The equation for uncertainty calculation is (3):

$$U_c(Elem.)\% = \sqrt{K_1^2 + K_2^2 + K_3^2 + \ldots + K_n^2} \qquad (3)$$

K is values of the uncertainties of the Ca and Sr results.

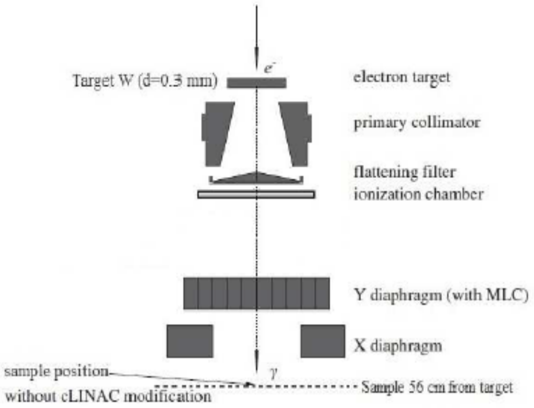


Fig. 2: Schematic view of the cLINAC

Table 1. Comparison of Universally Reference material (URM) and prepared calibration material by Schmitt B. F., Segebade C. and Fusban H.U.

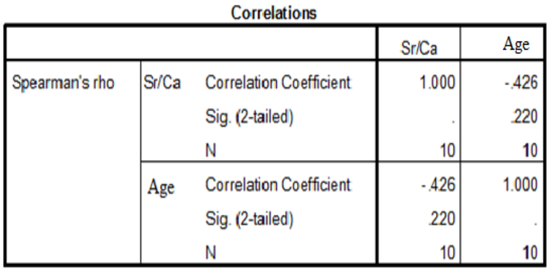
Element	^{87}Sr	^{48}Ca
Isotope	^{87m}Sr	^{47}Ca
keV	388	1297
Peak Sm.	266161.5	2472.83
Conc. Cal.	89258.21	78818.38
Conc. Sm.	30999 µg/g	68.85%
Lit. Value	778 ±38 µg/g	10.16% ±0.18%

3. Results and Discussion

In this study age dependence of the Sr/Ca ratio in 10 human teeth were examined. Photo-activation analysis was used for the detection of trace elements and amount of Sr/Ca ratio. Changes with respect to age and the effect of diet and environmental factors were investigated. This study is an example of first use of photo-activation analysis in our country for studies relating to health science. The value of Spearman's rho correlation (aka fit correlation coefficient) is -0.426 that calculated by using SPSS (Table 2). This value indicates a high negative correlation between age and Sr/Ca ratio. Sr/Ca ratio decreases with increasing age in the teeth. These relations are too high to be ignored. Because of the age factor can be explained only 9% of Sr/Ca rate. Calculated concentrations of Ca and Sr, and derived Sr/Ca ratios, in human teeth is shown in Table 3.

The remaining 91% factors are influenced by different factors such as climate, nutritional factors, genetic factor, gender and diet. While the age increase, the Sr/Ca ratio of teeth is decreasing 1/0.0026.

Table 2: The Value of Spearman's rho Correlation is calculated by SPSS



Correlations

			Sr/Ca	Age
Spearman's rho	Sr/Ca	Correlation Coefficient	1.000	-.426
		Sig. (2-tailed)	.	.220
		N	10	10
	Age	Correlation Coefficient	-.426	1.000
		Sig. (2-tailed)	.220	.
		N	10	10

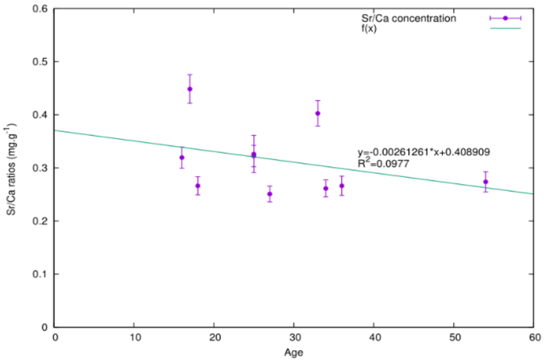


Fig. 3. The change of Sr/Ca ratios in teeth depending on age.

Table 3. Concentrations of Ca and Sr, and derived Sr/Ca ratios, in human teeth.

Sample No	**Age**	**Elemental Concentration**		**Sr/Ca(mg.g^{-1})**
		Ca (%)	**Sr(µg.g^{-1})**	
1	34	41(4)	106(5)	0.261(0.016)
4	25	43(5)	140(6)	0.322(0.021)
7	17	40(4)	179(8)	0.448(0.027)
8	33	40(4)	161(7)	0.403(0.025)
9	18	51(4)	136(7)	0.266(0.017)
10	54	37(4)	102(6)	0.274(0.019)
11	27	40(4)	99(5)	0.251(0.016)
13	36	35(4)	94(5)	0.266(0.018)
14	25	41(4)	220(11)	0.53(0.04)
17	16	40(4)	128(6)	0.320(0.020)
Mean ±SD				0.334±0.021

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