



## Evaluation of Uranium Levels in Zircon Dentures Using Neutron Activation Analysis Technology

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### Abstract

We conducted this laboratory study to evaluate the radiation risks in dental materials. We chose zirconium, which is used in the manufacture of artificial teeth, fillings and crowns, from ten different materials that we collected from authorized sales agents in Baghdad and some hospitals. We used the neutron activation analysis method because it is a non-destructive and accurate method that takes a good amount of time. After preparing the samples by grinding and pressing them in moulds, each sample weighing one gram, we placed them on a cross-sectional trace detector with the same dimensions. Then we introduced them to the radiator located in the laboratory of Ibn Al-Haitham College of Education. The advanced nuclear laboratory is based on the interaction ( $^{241}\text{Am} - ^9\text{Be}$ ) with an effectiveness of  $^{12}\text{Ci}$  and a neutron flux of  $10^5 \text{ n.cm}^{-2}.\text{sec}^{-1}$  For seven days after that, we counted the traces using a microscope and took the average of these traces and then subtracted it from the value of the background activity of the environment. Using equations, we calculated the net number of traces, the density of these traces, the specific activity, the absorbed dose, the equivalent dose, the effective dose, and the hazard factor. We compared them with the other two studies that used European-origin zirconium. The result was that the presence of natural uranium-238 was proven through the traces of helium particles that formed on our trace detector CR-39. The highest value we obtained for the equivalent dose was... which is still within the permissible range set by the International Atomic Energy Agency.

**Keywords:** Zirconium, CR-39, Neutron activation analysis, Dental restorative material.

### 1.Introduction

In the field of restorative dentistry, various materials are used to manufacture artificial teeth, crowns, bridges, fillings, braces, dentures, and adhesives<sup>1, 2</sup>. Among these materials are amalgam, glass composites, and zirconium. In this research, the element under study is zirconium, which is zirconium oxide used in the manufacture of teeth, as we mentioned, from teeth and dentures. It has many advantages, including biocompatibility with oral tissues, as it is insoluble in water, acid, or alkali. Due to its colour compatibility with the rest of the natural teeth in the mouth, it is opaque, so light does not pass through it<sup>3-7</sup>. It also does not conduct heat or cold to the nerves of the teeth. In addition, it can be fixed using adhesives or glass beads, and it does not accumulate bacteria in the contact area inside the gums. Dental manufacturing<sup>8 - 10</sup> materials contain percentages of heavy elements such as natural uranium-238, the concentration of which we will determine, and the presence of which leads to radioactivity that affects the tissues and cells surrounding the teeth or zirconium fillings. We have chosen 10 samples of zirconium from different origins were ground, then pressed into suitable moulds and

irradiated after placing pieces of the solid trace detector CR-39 adjacent to each sample<sup>11-13</sup>. The emission of alpha particles from the small concentrations of uranium present in the zirconium left traces on this detector. Using equations, we calculated the concentrations of uranium present in each sample, in addition to the absorbed dose, the equivalent dose, and the hazard factor for each sample. The purpose of this research was to evaluate the risks after knowing the concentration of uranium and its resulting hazard factor and comparing it with the globally permitted factor. It is worth noting that the standard for using zirconium in the dental industry has been set, which is that the radioactivity value of impurities present in its raw materials does not exceed 200 Bq/kg<sup>4,14</sup>.

## 2. Materials and Methods

The materials used were ten samples collected from different sources, government hospitals and authorized agents in Baghdad from different origins, as in **Table 1**.

**Table 1.** Samples by company, origin and location

Sample no.	Manufacturer	Origin	Sample collection location
1	Loden	China	Al Dora area / Abu Tayyara Street / Dubai Dental Center
2	Dental Plus USA	USA	Al Dora area / Abu Tayyara Street / Dubai Dental Center
3	Zechuan	China	Iraq/Baghdad/Bab Al-Muadham/High Summit Office for Dental Supplies
4	SHT	Lithuania	Al Dora area / Abu Tayyara Street / Dubai Dental Center
5	Zotion	China	Iraq/Baghdad/Bab Al-Muadham/High Summit Office for Dental Supplies
6	Straumann	Switzerland	Iraq/Baghdad/Bab Al-Muadham/High Summit Office for Dental Supplies
7	katana	Japan	Iraq/Baghdad/Bab Al-Muadham/High Summit Office for Dental Supplies
8	Sagemax	Greece	Iraq/Baghdad/Bab Al-Muadham/High Summit Office for Dental Supplies
9	Bloomden	U S A	Iraq/Baghdad/Bab Al-Muadham/High Summit Office for Dental Supplies
10	MINESMILE	China	Iraq/Baghdad/Bab Al-Muadham/High Summit Office for Dental Supplies

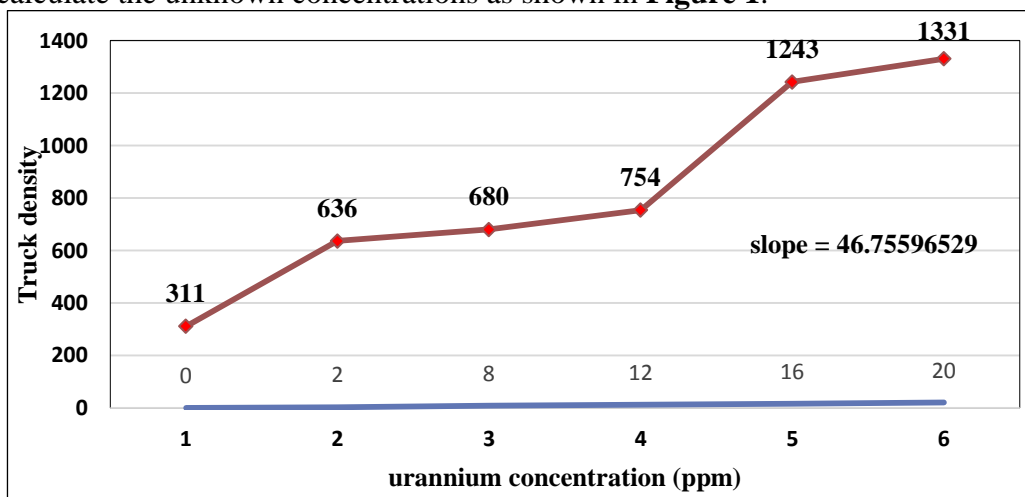
The laboratory materials were a sensitive and accurate balance, a hydraulic piston, an electric mechanical grinder, a manual grinder, a sieve, sturdy iron moulds, and a CR-39 solid trace detector<sup>15-18</sup>. A chemical skimming device containing a water bath<sup>19, 20</sup> with a temperature range up to 100 °C, distilled water, wire racks, and a light microscope. The samples were sorted, numbered, and coded to ensure that the results would not be mixed later. Then, the grinding process was carried out in two stages: the first using an electric grinder, and then using a manual grinder. They were smoothed and homogenized. After that, they were pressed into moulds with a diameter of one and a half centimeters, and we obtained discs with a thickness of one millimeter, a diameter of one and a half centimeters, and a weight of one gram. The structure of the discs was solid to ensure that they would not disintegrate when placed in the radiometer. Then, we stuck them on the CR-39 solid trace detector pieces after cutting them into squares with dimensions of one and a half centimeters<sup>21-22</sup>. Then, they were stuck on these pieces. Using transparent adhesive tape, the pieces were collected sequentially, so a strip of samples was formed. These samples were then placed in the American accelerator located in the College of Education, Ibn Al-Haitham, University of Baghdad, for a period of seven days. After that, we took out the samples and thought from the tape, took the pieces of the detector, washed them with water, and then placed them in a sodium hydroxide solution for the scraping process at a temperature of 60 in the chemical scraping device for three hours. Then they were washed and dried and read with a light microscope and the rate of effects was calculated for each detector that represents the sample that was placed on it. Through the equations, we calculated the

concentrations of uranium. As for the samples, we added a solution of uranium acetate to them, as in **Table 2** shown:

**Table 2.** Standard zirconia sample data

Uranium concentration (C <sub>x</sub> )ppm	traces density (ρ)	Traces average	Net traces
0	311	40	21
2	636	62	43
8	680	65	46
12	754	70	51
16	1243	103	84
20	1331	109	90

with known concentrations, and we drew a curve to obtain the slope through which we will be able to calculate the unknown concentrations as shown in **Figure 1**.



**Figure 1.** relationship of trace density with uranium concentration for standard model zirconia.

Since the slope value we obtained is 46.755 and by using the equations below we can calculate the concentrations of Anonymous samples as follows <sup>23-25</sup>:

$$C_x(\text{ppm}) = \frac{\rho_x}{\text{slope}} \times 0.278 \tag{1}$$

$$\rho_x = \frac{N_{ave}}{A} \tag{2}$$

$N_{ave}$  = The rate of quantitative effects within the area.,  $A$  = area = 0.0676 mm<sup>2</sup>  
 $D_{Ti} = 1.6 \times 10^{-10} \times S \cdot A \times E_r \tag{3}$

alpha particle energy used 4.2 Mev (**Table 3**)  
 $H_{Ti} = D_{Ti} \times W_R \tag{4}$

$$E_{Ti} = \sum W_{Ti} \times H_{Ti} \tag{5}$$

$$H_{ex} = \frac{(S.A)_{238U}}{185} \leq 1 \tag{6}$$

(S.A) = specific activity Bq/kg, (Hex) = Hazard index,  $D_{Ti}$ =Absorbed dose (mGy/y)

$H_{Ti}$  =The Equivalent Dose,  $E_{Ti}$  = effective doses (mSv/y)

**Table 3.** Symbols used in equations and their values

The symbol	Meaning	value
$E_{26}$	Alpha Energy	4.2 MeV
$W_R^{27}$	Alpha Radiation Weighting Factor	20
$W_{Ti}^{27}$	skin, bone surface Weighting Factor	0.01

### 3.Results

Through **Equation 1**, we calculated the density and uranium concentrations for the ten zirconium samples in succession and obtained **Table 4**.

**Table 4.** Rate and density of traces and uranium concentrations

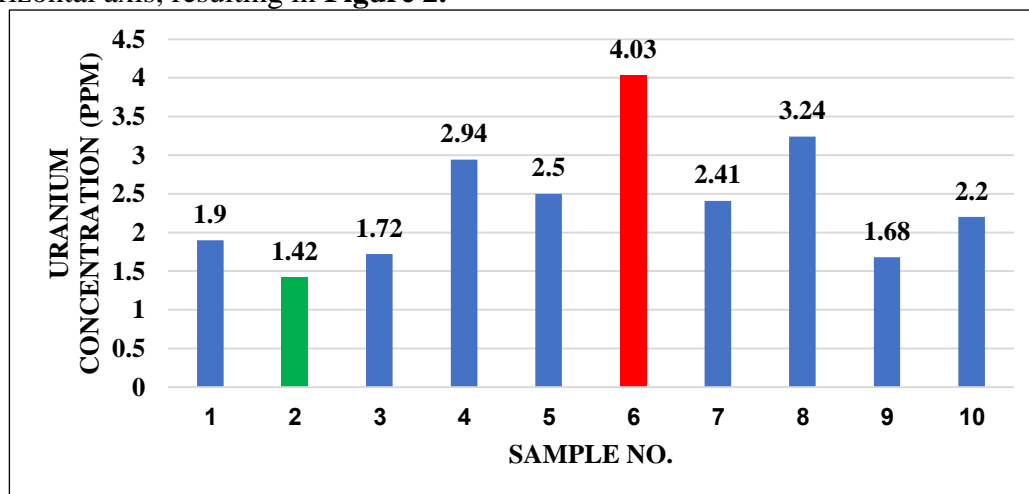
zirconia sample	Traces average	Net traces	traces density ( $\rho$ )	Uranium concentration ( $C_x$ ) ppm
1	41	22	319 ± 147.15	1.90±0.87
2	35	16	239 ± 109.52	1.42±0.65
3	39	20	290 ± 113.90	1.72±0.68
4	52	33	495 ± 56.56	2.94±0.34
5	47	28	421 ± 44.26	2.50±0.26
6	65	46	678.36 ± 196.33	4.03±1.17
7	46	27	406 ± 240.49	2.41±1.43
8	56	37	545 ± 132.70	3.24±0.79
9	38	19	283 ± 128.8	1.68±0.77
10	44	25	370 ± 139.29	2.20±0.83

And using **Equation 6**, we were able to calculate the Hazard index and **Equation 3** to calculate Absorbed dose, **Equation 4** to calculate the Equivalent Dose and **Equation 5** to calculate effective doses as shown in **Table 5**.

**Table 5.** Specific activity, sustained dose, equivalent dose, absorbed dose, reward, effective dose, and Hazard index

zirconia sample	specific activity (S.A) Bq/kg	Hazard index ( $H_{ex}$ )	Absorbed dose (mGy/y) $D_{Ti}$	The Equivalent Dose ( $H_{Ti}$ )	effective doses (mSv/y) For bone and skin surfaces ( $E_{Ti}$ )
1	23.43 ± 10.81	0.127	0.489	9.782	0.196
2	17.54 ± 8.04	0.095	0.366	7.323	0.146
3	21.26 ± 8.36	0.115	0.444	8.876	0.178
4	36.31 ± 4.15	0.196	0.758	15.159	0.303
5	30.88 ± 3.25	0.167	0.645	12.892	0.258
6	49.81 ± 14.42	0.269	1.040	20.795	0.416
7	29.79 ± 17.66	0.161	0.622	12.437	0.249
8	40.04 ± 9.74	0.216	0.836	16.716	0.334
9	20.79 ± 9.46	0.112	0.434	8.679	0.174
10	27.16 ± 10.23	0.147	0.567	11.339	0.227

To illustrate the differences in uranium concentrations for samples from different origins, we used uranium concentration data from **Table 4** on the vertical axis and arranged the samples on the horizontal axis, resulting in **Figure 2**.

**Figure 2.** Relationship of sample number and uranium concentration in zirconia.

We also examined the differences in the effective dose for samples from different origins. Data were taken from **Table 5**, plotted on the vertical axis, and the samples were arranged on the horizontal axis, resulting in **Figure 3**.

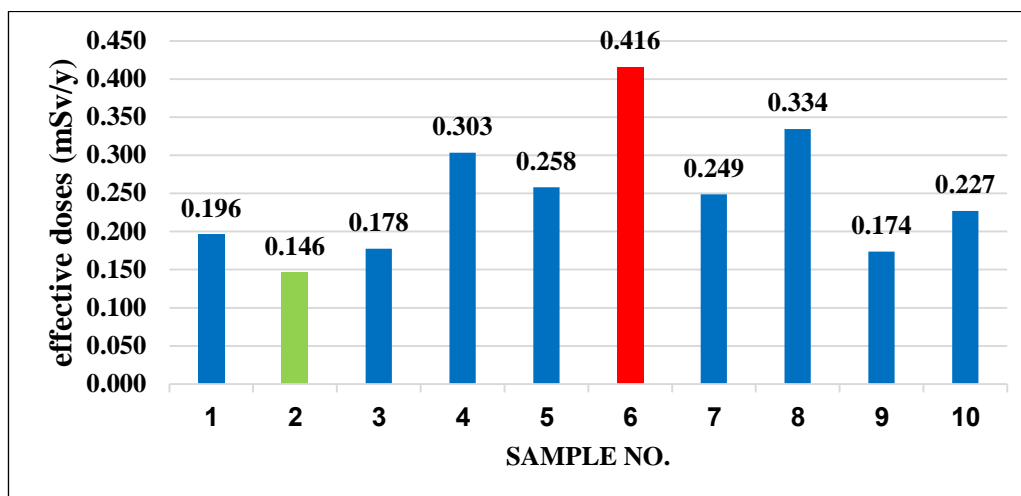


Figure 3. sample number and effective dose of zirconia.

#### 4. Discussion

The ten samples had varying uranium concentrations showed in **Table 4**. The lowest value that appeared was 1.42 ppm for sample number 2, and the highest value that appeared was 4.03 ppm for sample number 6. Also, the effective dose, which follows the concentration values, was from the lowest value, which was 0.146 mSv/y, to the highest value, which was 0.416 mSv/y. Comparing this to the results of a study titled "Zirconia and radioactivity: An in vitro study to establish the presence of radionuclides in dental zirconia"<sup>28</sup> conducted in Spain on three samples of raw zirconium used in dental implants, the highest radioactivity value was 34.91 Bq/kg, which in our research was  $49.81 \pm 14.42$  Bq/kg. The method used was gamma spectrometry to measure radioactivity. The alpha decay of uranium was monitored, proving the presence of radionuclides within the zirconium used in dentistry. In another study titled "Natural radioactivity in zirconia-based dental ceramics"<sup>29</sup>, the highest radioactivity value was 9.9 Bq/kg.

#### 5. Conclusion

Based on the results of our laboratory study, we reached this conclusion. Firstly, the presence of uranium-238 radionuclides in all zirconium samples indicates the presence of this type of impurity. Secondly, we obtained did not exceed the effective dose, as the highest value we obtained is 0.744 mSv/y, within the IAEA safety standards of 1 mSv/y. Thirdly, doses were per gram, meaning that any increase in weight means an increase in the number of radionuclides. Finally, People with dental fillings or artificial teeth are more susceptible to structural doses than others.

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#### Conflict of Interest

The authors declare that they have no conflicts of interest.

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