Nuclear Engineering and Technology 56 (2024) 3898–3903

Contents lists available at ScienceDirect

Nuclear Engineering and Technology

journal homepage: www.elsevier.com/locate/net

Original Article

The radioactivity levels and beta dose rate assessment from dental ceramic materials in Egypt

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ARTICLE INFO

Keywords:
NaI(Tl) detector
Feldspathic ceramics
Zirconia-based ceramics
Natural radioactivity

ABSTRACT

There is a lack of available data on the radioactivity levels of these materials, despite the potential risks they may pose to patients, dental technicians, and dentists. A total of forty samples were collected from different dental markets in Egypt. Using an NaI(Tl) detector, the gamma-ray spectrometer measured the activity levels of uranium-238, radium-226, thorium-232, and potassium-40. The findings revealed that the mean concentration of ^{238}U (below the minimum detectable activity, MDA), ^{226}Ra (135 ± 5 and 132 ± 5 Bq/kg), ^{232}Th (187 ± 4 and 243 ± 8 Bq/kg), and ^{40}K (1560 ± 52 and 2501 ± 89 Bq/kg) in feldspar and zirconia (ZrO_2) dental ceramic samples, respectively, were all within the limits established by the International Organization for Standardization (ISO) and the European Commission (EC). The use of feldspar and zirconia dental ceramics to restore all teeth would result in an estimated maximum beta dose of 1.5 mGy/year to the oral tissue. The results suggest that there is no cause for concern regarding any additional beta dose to the oral cavity from the use of feldspar and zirconia dental ceramics.

1. Introduction

Terrestrial and cosmic radiation are the two primary sources of natural radioactivity that have an impact on our everyday lives. Ionizing radiation is emitted continuously by naturally occurring radioactive materials (NORMs). The passage above explains that there are two types of radiation exposure: external and internal. External exposure occurs when individuals are exposed to gamma rays emitted by radionuclides such as uranium-238, thorium-232, and potassium-40 found in the Earth's crust. Conversely, internal exposure occurs when individuals inhale radon gas, a radioactive gas present in buildings and underground [1–4]. There has been increasing interest in investigating the potential health hazards linked to prolonged exposure to radiation [32,33].

Restorative materials such as feldspathic and zirconia-based ceramic are most commonly used in dental prosthetics due to their mechanical and esthetic properties. Like other materials found in nature, these materials contain trace amounts of radionuclides. Excessive radioactive materials in restorative materials could be harmful to health by causing cell mutation and damage [5,6]. Alpha, beta particles and gamma rays are ionizing radiation emitted by radionuclides, in particular, the absence of alpha particles in the oral cavity is due to the maximum size in tissues is 30 μm, and alpha particles can already be absorbed by saliva and plaque surrounding the restoration before reaching radiosensitive tissues within the oral cavity, it may play only a minor role in tissue reaching the basal layer of the oral mucosa [7,8]. Compared to alpha particles, beta particles and gamma rays may have a wider tissue

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https://doi.org/10.1016/j.net.2024.04.036
Received 5 March 2024; Received in revised form 18 April 2024; Accepted 24 April 2024
Available online 26 April 2024

absorption range, exposing more tissue [9,10]. Depending on the energy of the gamma ray, all oral mucosal tissues are dosed [11].

Feldspathic ceramics are made up of 70–75 % potassium aluminium silicate (K_2O_2 Al_2O_3, $6SiO_2$) and albite (Na_2O, Al_2O_3, $6SiO_2$), 15–20 % quartz (SiO_2), and very little (or perhaps none) kaolin (Al_2O_3, $2SiO_2$, $2H_2O$) [12]. Feldspar is not always present in its purest form in nature and can contain varying levels of potassium oxide (K_2O) and sodium oxide (Na_2O) [13]. On the other hand, Zirconia based ceramics are composed of Yttrium-stabilized tetragonal zirconia (3Y-TZP), the chemical element zirconium (Zr) is not found in nature in its pure form, but occurs as either ZrO_2, baddelleyite, or $ZrSiO_4$, zircon, which occurs together with rutile, ilmenite, or monazite. Zirconia is a polymorphic oxide appears in cubic, tetragonal, and monoclinic crystal forms, respectively. Feldspathic and ZrO_2 are refined from naturally occurring ores, and contains significant concentrations of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K depending upon where the crystals have been mined and the geologic process. According to safety reports radioactive impurities have to be taken into account from feldspathic and ZrO_2 because these radionuclides especially used in medical areas [14–16].

There is a paucity of data on the level of radioactivity in dental restorative materials. Due to the fact that the level of radioactivity depends on the concentration of radionuclides in the dental material, the radioactive concentration of such a dental restorative material is very important in assessing the potential risks of radiation exposure from these restorative materials in terms of the problems that may arise for patients, dental technicians and dentists. For example, it is possible for a dental technician to be exposed to radiation hazards from presintered form with dust during the milling process, the patient was cured using a ceramic material containing radionuclides, therefore the potential risk of radioactivity associated with the use of these materials was a concern [17–19].

This study aims to assess the potential risks that could be posed to human health by the radionuclides present in common dental restorative materials in the Egyptian market such as feldspathic ceramics and zirconia ceramics in terms of Uranium-238, Raduim-226, Thorium-232 and Potassium-40 activity concentration using a gamma ray spectrometer NaI(Tl) detector and compare the results with international standards to determine if the clinical use of these materials is safe.

2. Materials and methods

2.1. Sample preparation

Feldspathic and zirconia (ZrO_2) dental ceramics which are commonly available in the Egyptian dental market were the subject of this research. Forty different ceramic powders used for opaque, dentin, enamel and transparent applications, were collected from five different brands of zirconia (ZrO_2) dental ceramics and two different brands of feldspathic dental ceramics. Table 1 shows the ceramic typology of dental ceramic systems with compositions and manufacturers.

The ceramic samples studied are classified according to their shades and types (layering ceramic types) are shown in Table 2. All these samples were obtained in the form of powder. All samples collected were kept in polyethylene bags and placed in plastic containers 75 mm in diameter and 90 mm in height. The samples were weighed and stored for a minimum of one month to allow the daughter products to reach radioactive equilibrium with their parents, Raduim-226 and Thoruim-232, and then counted with an average count time of 86,400 s, depending on the radionuclide concentration.

2.2. Radioactivity measurements

The dental ceramic samples were analyzed using NaI(Tl) gamma ray spectrometer at the Physics Department of Assiut University, with 8192 multichannel analyzer, the resolution (FWHM) at 1.33 MeV gamma line ^{60}C is 60 keV and the relative efficiency at 1.33 MeV energy line of ^{60}C is 7.5 %. The detector has a two-layer chamber consisting of 1 cm of stainless steel and 3 cm of lead. This protection (shielding) helps to

Table 1
Typology and composition of ceramic samples from different manufactories.

Ceramic Typology	Composition	Manufacturer
Nacera®Pearl Natural	3Y-TZP (ZrO_2 + HfO_2 + Y_2O_3)	Doceram Medical Ceramics GmbH, Spenge, Germany.
XTCERA 3D Multilayer	ZrO_2 + HfO_2 + Y_2O_3 + Al_2O_3	Shenzhen Xiangtong Co., Ltd., Shenzhen, China.
Natura Z	ZrO_2 93 ± 0.5 HfO_2 1.5 ± 0.5 Y_2O_3 5 ± 0.5 $Al_2O_3 \leq 1$ $Fe_2O_3 \leq 1$	DMAX Co., Ltd., Daegu, Korea.
Zotion	- ZrO_2 + HFO_2 + Y_2O_2 - Y_2O_3 - Al_2O_3	Chongqing Zotion Dentistry Technology Co. Ltd, Chongqing, China.
Katana™ Zirconia	- ZrO_2 90–95 %, - Y_2O_3 5–8% - Other <2 %	Kuraray Noritake GmbH, Hattersheim, Germany.
Vita VMK master	Natural potassium ($KAISi_3O_8$), orthoclase and sodium bicarbonate feldspars ($NaAISi_3O$; albite)	VITA Zahnfabrik H. Rauter GmbH & Co. KG. Bad Säckingen, Germany.
GC Initial® MC	Feldspathic porcelain. Exact composition not specified by the manufacturer.	GC Corporation Bunkyo-ku, Tokyo, Japan.

Table 2
Characteristics of the measuring ceramic samples.

Brand	Sample code	Shade	Ceramic Type
Nacera	N1	A1	Translucent
	N2	A1	Translucent
	N3	B1	Translucent
	N4	B2	Translucent
	N5	C1	Translucent
	N6	C1	Translucent
XTCERA	X1	A1	Full anatomical
	X2	A1	Full anatomical
	X3	B1	Full anatomical
	X4	B2	Full anatomical
	X5	C1	Full anatomical
	X6	C1	Full anatomical
Natura Z	T1	A0	Opaque
	T2	A0	Opaque
	T3	A0	Opaque
	T4	A0	Opaque
Zotion	Z1	A1	3D multilayer STM
	Z2	B1	3D multilayer STM
	Z3	C1	3D multilayer STM
	Z4	A1	3D multilayer STM
	Z5	B1	3D multilayer STM
	Z6	C1	3D multilayer STM
Katana	K1	A1	Yttria multilayered
	K2	A1	Yttria multilayered
	K3	B1	Yttria multilayered
	K4	B2	Yttria multilayered
	K5	C1	Yttria multilayered
	K6	C1	Yttria multilayered
Vita VMK master	V1	OP2	Opaque
	V2	OP2	Opaque
	V3	2M3	Dentine
	V4	2M3	Dentine
	V5	EN2	Enamel
	V6	EN2	Enamel
GC Initial MC	G1	A1	Opaque
	G2	A1	Opaque
	G3	A1	Dentine
	G4	A1	Dentine
	G5	A1	Enamel
	G6	A1	Enamel

reduce the difference in background radioactivity. The detector (3 × 3 inches) is located in the center of the chamber to minimize the amount of radiation lost through the shield.The spectra were evaluated using the Maestro software program (EG&G ORTEC).

Specific activity concentrations (Bq/kg) of nuclide i and energy peak E, A are given by Eq. (1) [20]:

$$A = \frac{C_n}{t_c \times I\gamma\ (E\gamma) \times \varepsilon\ (E\gamma) \times M} \quad (1)$$

Where C_n is the counts rate of each energy peak (Eγ) subtracted from background, t_c is the measurement time in second, Iγ (Eγ) is the gamma-ray emission probabilities at the energy Eγ, ε (Eγ) is the absolute detector efficiency at energy Eγ, and M is the mass in kilograms of the sample measured. The ^{226}Ra activities were analyzed from the photopeaks of ^{214}Pb (295.22, 351.93 keV) and ^{214}Bi (609.31, 1120.29, 1764.49 keV). The ^{232}Th analyzed from ^{228}Ac (911.2, 968.97 keV), ^{212}Pb (238.63 keV) and ^{208}TI (583.19, 2614 keV), while ^{40}K was analyzed from the 1460.8 keV.

The detector was calibrated for energy and efficiency calibration, for energy calibration radioactive source of known energy such as ^{137}Cs (662 keV) and ^{60}Co (1332 and 1172 keV) was used, while efficiency calibration, a simple technique that estimate the efficiency of a NaI(Tl) detector using the known activities concentration of environmental sample with specific activities (6421.90 ± 206.25 Bq/kg for ^{226}Ra, 2451.09 ± 96.51 Bq/kg for ^{232}Th, and 285.50 ± 16.71 Bq/kg for ^{40}K) and has a container with similar geometry of the samples under investigated [21].

Minimum detectable activity (MDA) for each radionuclides were calculated by the Currie method [3], which is presented in Eq. (2):

$$MDA = \frac{2.71 + 4.65\sqrt{C_{BG}}}{\varepsilon \times I\gamma \times M \times T_{BG}} \quad (2)$$

where MDA is in Bq/kg (confidence level 95 %), C_{BG} is the background at energy E, ε is detector efficiency, Iγ is the gamma-ray emission probabilities at energy E, T_{BG} is the background counts time and M is the sample mass. The values of MDA were 0.88 (Bq/kg) for Radium-226, 1.18 (Bq/kg) for Thorium-232and 1.46 (Bq/kg) for Potassium-40.

3. Results and discussion

3.1. Activity concentrations in dental ceramics

Table S1shows the measurement of activities concentration of ^{238}U, ^{226}Ra,^{232}Th, and ^{40}K for Feldspathic and zirconia (ZrO_2) dental ceramics samples. Table 3 presents the descriptive analysis of the activity concentration of ^{238}U, ^{226}Ra,^{232}Th' where ^{238}U content in all samples was found to be below MDA. Moreover, the activity of ^{226}Ra from zirconia (ZrO_2) dental ceramics samples varied from 67 ± 3 Bq/kg to 169 ± 8 Bq/kg with an average range of 135 ± 5 Bq/kg, while in feldspar dental ceramics varied from 83 ± 4 Bq/kg to 162 ± 8 Bq/kg with an average range of 132 ± 5 Bq/kg. The ^{232}Th activity levels contents in zirconia samples varied from 71 ± 3 Bq/kg to 290 ± 11 Bq/kg with an average range of 187 ± 4 Bq/kg, and from feldspar varied from 140 ± 7 Bq/kg to 295 ± 8 Bq/kg with an average range of 243 ± 8 Bq/kg. In regards to ^{40}K in zirconia samples, the activity levels varied from 600 ± 30 Bq/kg to 2474.05 ± 114 Bq/kg with an average range of 1560 ± 52 Bq/kg, and from Feldspar varied from 1014 ± 50 Bq/kg to 3574 ± 101 Bq/kg with an average range of 2501 ± 89 Bq/kg. Feldspathic and zirconia samples contain relatively high levels of ^{40}K compared with ^{226}Ra, ^{232}Th that is due to the fact that, potassium is one of the constituting elements of feldspar [22,23], the basic structure in the feldspathic ceramic prostheses is mainly composed of feldspar and silica. All measured activities concentration of ^{226}Ra,^{232}Th, and ^{40}K from dental ceramics samples under investigation were found above MDA except sample N2 in ^{40}K concentration, while in ^{238}U concentration all samples were below MDA. All the dental ceramics samples were found below the standard limits set by the International Organization for Standardization (ISO) and the European Commission (EC). (10,000 Bq/kg for ^{40}K, 1000 Bq/kg for ^{238}U and 1000/Bq kg for ^{232}Th) [24,25] as shown in Table 3. The average activity concentration of ^{232}Th for zirconia and feldspar samples was approximately 5 times and 4 times lower than exemption limits, the average activity levels of ^{40}K for zirconia and feldspar samples were approximately 6 times and 4 times lower than exemption limits. This indicates that, according to our results, the activity levels in the dental ceramic samples studied do not pose a significant potential radiological risk.

According to Phil-Eze's (2010) research, variability can be classified using CV values. CV values below 20 % are considered low, 21–50 % are moderate, 51–100 % are high, and values above 100 % are considered very high [26]. Low CV values for ^{226}Ra, and ^{232}Th, in feldspathic and zirconia indicate a consistent distribution and dominance of specific sources, while moderst CV values of ^{40}K and suggest a wide range of radionuclide sources [27,28]. In general, the distribution of ^{40}K activity concentrations shows the greatest variation during feldspathic and zirconia dental ceramic, as indicated by Table 3. The distribution frequency of all associated radionuclides was analyzed and can be seen in the histograms displayed in Fig. 1(a-f). According to Kolmogorov Smirnov (KS) normality test, a normal distribution was observed for ^{226}Ra, ^{232}Th and ^{40}K in the feldspathic and zirconia dental ceramic (See, Tables S1 and S2).

The study also used key statistical parameters including skewness and kurtosis. The analysis of skewness data revealed an asymmetric distribution of radioelement activity concentrations, with positive values indicating asymmetry. While their negative findings pertain to the tail end of the skewed distribution, which includes negative data. Thus, in the feldspathic dental ceramic, the presence of positive skewness in the data of ^{232}Th and ^{40}K activity concentrations indicates a positive asymmetric distribution, whereas the negative skewness in the data of ^{226}Ra activity concentrations indicates a negative asymmetric distribution. The activity concentrations of all radionuclides in zirconia dental ceramic were found to have negative skewness values. In addition, the kurtosis coefficients indicate the asymmetry of the distribution probabilities. The kurtosis coefficients for the radioelement ^{226}Ra are greater than 1, indicating that the distributions of normal and activity levels are not symmetric in both feldspathic and zirconia dental ceramics. The kurtosis coefficient of ^{40}K showed negative values, indicating a flatter probability distribution. For zirconia dental ceramic, the

Table 3
Descriptive analysis of^{226}Ra,^{232}Th, and^{40}K concentrations in feldspathic and zirconia (ZrO_2) dental ceramics samples.

	N	Mean	SD	Min	Max	Skewness	Kurtosis	Cv, %
Feldspathic								
^{226}Ra	28	135	24	67	169	−0.91	1.00	18
^{232}Th	28	187	54	71	290	0.05	−0.25	29
^{40}K	27	1561	564	600	2474	0.12	−1.25	36
Zirconia								
^{226}Ra	12	132	22	83	162	−0.90	1.05	17
^{232}Th	12	243	46	140	295	−1.18	1.22	19
^{40}K	12	2501	829	1014	3574	−0.61	−0.41	33

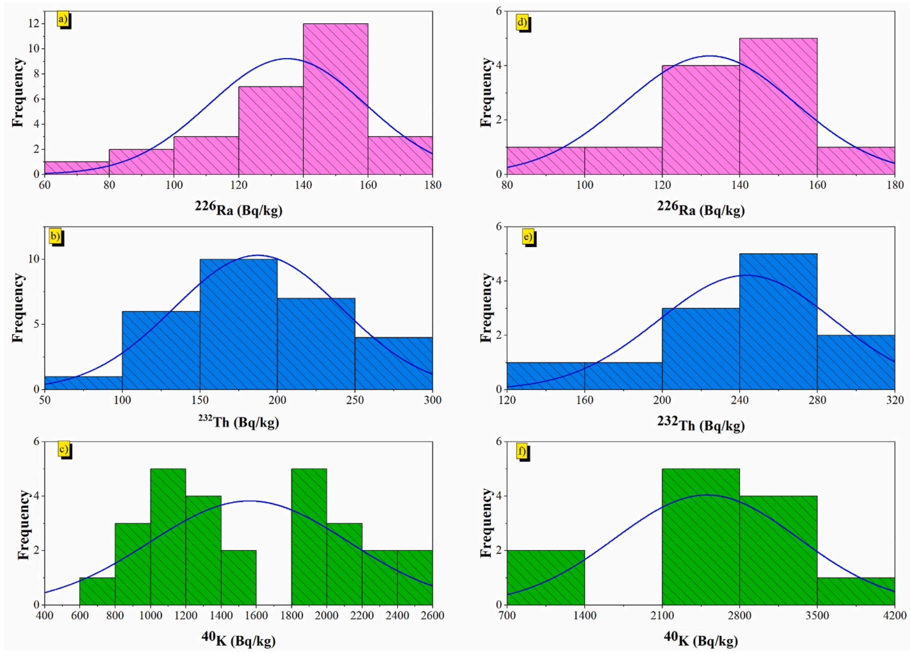

Fig. 1. The normal probability distribution of ^{226}Ra, ^{232}Th, and ^{40}K activity concentrations in a,b,c) feldspathic dental ceramic and d,e,f) zirconia dental ceramic.

kurtosis coefficient for ^{232}Th activity concentration was found to be positive, while for feldspathic dental ceramic, it was found to be negative. According to Table 3, the standard deviation values for the radionuclides ^{226}Ra, ^{232}Th and ^{40}K are lower than their respective means. This indicates a high degree of consistency in the predicted radionuclide levels in the feldspathic and zirconia dental ceramic samples.

Fig. 2 (a,b) shows the comparison of the mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K for different feldspathic and zirconia ceramics brands. For feldspar, brand Z had the highest ^{226}Ra values, brand N had the lowest values, brand X had the highest values for ^{232}Th and ^{40}K, and brand K had the lowest values. In contrast, zirconia brand G was slightly higher than brand V for ^{226}Ra, ^{232}Th, and ^{40}K values.

The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in feldspathic ceramics samples in the present study were compared with other studies and a summary of the results is shown in Table 4. The results showed that the average activity concentration of ^{226}Ra in the present study is much higher than those in the literature [23,29] while literature [11,18] reported that the natural radioactivity was not available in studies. On the other hand, the results by literature [29] show only ^{232}Th activity concentrations, which were much lower than the present study. In the average activity concentrations of ^{40}K, the present study was in agreement with the corresponding results from other studies.

Table 4
Comparison of average activity concentration from feldspathic ceramics with previous studies.

^{238}U	^{226}Ra	^{232}Th	^{40}K	References
372.3	NA	NA	2729	[11]
NA	NA	NA	2010–2900	[30]
MDA	26.2	MDA	2300	[6]
126	12.7	5.6	2855	[29]
MDA	132	243	2501	Present study

NA: Not Available, MDA: Minimum Detectable Activity.

3.2. *Comparison between the teeth's ceramic type*

Furthermore, the activities of ^{226}Ra, ^{232}Th, and ^{40}K in the feldspathic ceramic powders were assessed based on the different types of ceramics. To achieve this objective, a total of 40 specimens were examined and divided into seven groups based on their ceramic type: translucent, full anatomical, opaque, 3D multilayer STM, yttria multilayered, dentin, and enamel. The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K were then calculated for each group and recorded in Table 5. The activity concentrations of radium in 3D multilayer STM, opaque and full anatomical ceramics were found to be higher than the average levels

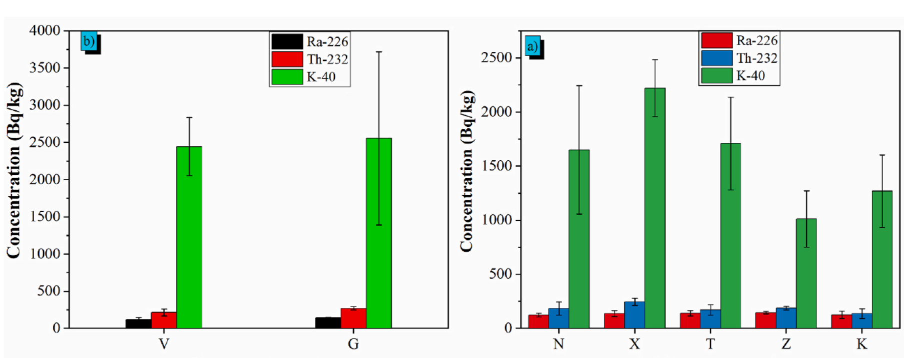

Fig. 2. The average activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K from a) feldspathic and b) zirconia ceramics brands.

Table 5
The average ^{226}Ra, ^{232}Th, ^{40}K activities (Bq/kg) and beta dose in 10 years of the specimens according to their ceramic types.

n	Ceramic type	^{226}Ra	^{232}Th	^{40}K	D_T µGy/s	Total dose in 10 years mSv/y
6	Translucent	123 ± 17	185 ± 61	1651 ± 592	4.7E-05	14.9
6	Full anatomical	139 ± 29	247 ± 34	2223 ± 264	4.4E-05	13.9
4	Opaque	141 ± 23	182 ± 55	1914 ± 469	3.4E-05	10.7
6	3D multilayer STM	147 ± 12	189 ± 16	1014 ± 261	2.0E-05	6.4
6	Yttria multilayered	127 ± 33	138 ± 44	1271 ± 335	2.5E-05	8.0
6	Dentine	119 ± 25	245 ± 24	3084 ± 367	4.9E-05	15.3
6	Enamel	132 ± 17	244 ± 47	2721 ± 690	5.1E-05	16.0

found in translucent, yttria multilayered, dentin and enamel, ceramics. The descending order of ^{232}Th activity concentrations is as follows: full anatomical > dentine > enamel > 3D multilayer STM > translucent > opaque > yttria multilayered. The elevated levels of radium and thorium in the feldspathic ceramic samples could be attributed to the higher presence of fluorescence agents for example in opaque and dentin ceramics, as the fluorescence of natural teeth is primarily dependent on dentin tissue [31]. Therefore, dentin ceramics may contain a greater amount of these agents compared to transparent ceramics. Table 5 demonstrates that the average ^{40}K concentrations of the 7 ceramic groups exhibited a consistent reverse pattern.

3.3. Beta dose rate assessment

Durkan et al., 2020 proposed a new model to assess the beta dose rate deposited in the prosthetic materials of the dental system [23]. In this model, the activity concentration of potassium only given in Table 5 is used to assess the beta dose. The Durkan model reported that the beta particles are the primary irradiated source to the entire oral epithelium and the alpha and gamma photons are negligible. Based on the model, the beta dose results in the present study (Table 5) show that the total dose in 10 years in the worst case exceeds 15 mSv. Thus, the results are in agreement with the results of Durkan et al., 2020, which confirmed a non-significant risk.

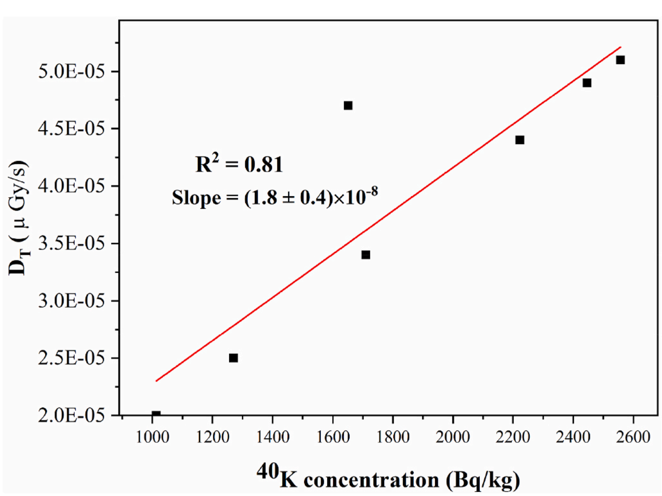

Fig. 3. The linear correlation between the specific activities of ^{40}K, determined through gamma-spectrometry measurements, and the annual total beta dose rates (D_T).

In Fig. 3 the linear correlation between the specific activity of ^{40}K determined by gamma spectrometry and the net sample beta dose rate is plotted. The net sample beta dose rate is calculated by subtracting the background value from the gross dose rate. The elevated levels of high beta radiation in feldspar and zirconia dental ceramic samples are mainly due to the natural occurrence of ^{40}K in these materials. A strong correlation ($R^2 = 0.81$) can be observed between the specific activity of ^{40}K and the beta dose rate, with the line of best fit intersecting the origin of the axis system. On the other hand, the slope of the line, $(1.8 \pm 0.4) \times 10^{-8}$ mGy $y^{-1}(Bq\ kg^{-1})^{-1}$, is greater than 1. It is evident from numerous samples that the measured dose rate is higher than the expected value calculated on the basis of the ^{40}K concentration.

4. Conclusion

Feldspar and zirconia ceramics have been studied because of the potential health risks from their natural radioactivity. The average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K from zirconia ceramics were 135 ± 5 Bq/kg, 187 ± 4 Bq/kg, 1560 ± 52 Bq/kg, and from feldspar ceramics were 132 ± 5 Bq/kg, 243 ± 8 Bq/kg, 2501 ± 89 Bq/kg. All dental ceramic samples examined were below the standard limits set by the International Organization for Standardization (ISO) and the European Commission (EC).The results of total beta dose rate in 10 years exceed 15 mSv/y for dentin (15.3 mSv/y) and enamel (16 mSv/y) ceramics. These beta dose results indicate that the feldspar and zirconia-based ceramics don't pose a significant radiological risk to patients. Thus, all ceramic samples can be considered safe for use as dental restorative materials.The high beta dose in feldspathic and zirconia dental ceramic samplesis attributed to the presence of ^{40}K in the materials.Furthermore, this study is the first of its kind in Egypt focusing on dental restorative materials such as feldspathic and zirconia-based ceramics. The results of this research can serve as valuable reference data for future studies. Therefore, it is crucial to conduct comprehensive measurements to minimize radiation exposure to the public.

Conflict of interest

No potential conflict of interest was reported by the author.

Data availability

The data used to support the finding of this study are available upon request.

CRediT authorship contribution statement

Mohamed Hasabelnaby: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Mohamed Y. Hanfi:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft. **Hany El-Gamal:** Data curation, Formal analysis, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Ahmed H. El Gindy:** Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review & editing. **Mayeen Uddin Khandaker:** Formal analysis, Funding acquisition, Investigation, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. **Ghada Salaheldin:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.net.2024.04.036.

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