Radioactivity of Materials used in Prosthodontics: An Overview.

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Abstract
Objective: Dental materials used in prosthodontics and restorative dentistry include materials with radioactive properties. The sources of radioactivity in dental materials are covered in this overview, along with their geological origins and production methods.
Background: Dental office personnel require extensive knowledge on radioactivity and radiation from the materials used in dentistry. Available literature is sparse with limited studies on their adverse effects.
Methodology: Articles published were collected and reviewed to gain an insight on this topic and the search has been done electronically between 2006 and 2023.
Results: Zirconia, glass based ceramics, feldspathic ceramics and resin based materials have a potential for radioactivity
Conclusion: Emphasis must be placed on measures of radioactivity in dental materials, quality control and regulatory standards for dental personnel. There is a need for more studies to determine the true effects on dental professionals and patients.
Application: Possible health hazards of prolonged radiation exposure must be borne in mind while choosing restorative options.

Keywords: Radioactivity, radiobiology, radioactive hazard release.

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Introduction
A wide range of materials are employed in prosthodontics to fabricate prostheses. The adverse impacts and occupational dangers of the materials must be understood. Few studies have been conducted on the radiation impacts of the materials utilized, and practicing dentists and technical staff who handle the materials are often unaware of this. Radioactivity was found in feldspathic ceramics in earlier investigations. [1] Recent research has focused on zirconia because it is the most popular ceramic material right now and the existence of radionuclides in zirconia is confirmed by various studies. [2-4]

Review

Radiation
The energy that travels through space as waves or particles is known as radiation. Radiation can be particulate, such as alpha and beta particles, or electromagnetic, such as radio waves and gamma rays. The phenomenon when the nucleus of an atom of an element undergoes spontaneous and uncontrollable

disintegration (or decay) is known as radioactivity.[5] In dentistry, radioactivity-the ability of some materials to release radiation-is a feature that is frequently disregarded. It does, however, have important ramifications for patient safety, the environment, and the general standard of dental care.

Mechanism of Radiation

When a photon beam passes through these high-density materials, the distribution of photon dosage in heterogeneous media is altered. At the tissue-metal contact, there is an increase in dosage when a metal is present in the radiation field. This boost results from the interaction of ionizing radiation with the metal's atoms, which releases and activates internal electrons in the metal. Secondary electrons are created by radiation contact with electron-dense materials, including metals, when high-energy radiation (photons) interact with them. This phenomenon, known as "Radiation backscatter," causes neighbouring tissues to receive an extra, unwanted dose. [1] Radiation can be ionizing or nonionizing radiation by the way they interact with matter. Ionising radiation, alpha, beta, and gamma radiation, loses or gains electrons as it interacts with atoms. Non-ionizing radiation does not displace the electrons from the atom; examples: visible light and radio waves. [2,5]

Sources of Radiation

Radioactivity is ubiquitous and occurs spontaneously. All matter was created by nuclear reactions, and we are constantly exposed to radiation. Approximately 95% of the 5000 plus known atoms are radioactive. Both natural and artificial sources can emit radiation. Background radiation is another name for natural radiation. The sources of background radiation can be classified as internal, terrestrial, or space-based. The decay of radioactive elements found in rocks, soil, and other materials produces terrestrial radiation. Natural minerals account for the majority of background radiation, with man-made elements contributing only a small portion. Natural background radiation is influenced by minerals that are present in soil and water. The background radiation is also explained by cosmic radiation from extra terrestrial space. Natural radionuclides that enter the body cause internal radiation.[6]

Industrial, medicinal, and consumer goods are examples of man-made sources. Commercial aviation, smoke detectors, and clocks are examples of consumer goods that use radioactive elements to work. Additionally, radiation is employed for medicinal and diagnostic purposes. In nuclear medicine, radioactive elements are injected into particular bodily parts, and imaging is used to detect and cure cancers. Examples of industrial and occupational radiation sources include emissions from nuclear power stations, uranium mines, and fuel processing facilities.

Measurement of Radiation

The rate of radioactive decay can be used to quantify the amount of radiation present in the environment. It is expressed in Curie (Ci). 1 Ci = 3.7E+10 (37,000,000,000) atom disintegrations per second (dps). 1 dps = 1 Becquerel (Bq). The radiation absorbed by a person is measured in terms of dose. A dose is the amount of radiation energy absorbed by the body. It is expressed in rad. 100 rad equals 1 Gray (Gy). The amount of potential biological damage caused by radiation exposure to and subsequent absorption is expressed in terms of rem.[5]

Radioactivity

Normal threshold dose for radiation protection is 0.5 Gy. Maximum levels permitted by the International Atomic Energy Agency (IAEA) Safety Standard Series No. RSG1.7, 2004 and ISO 6872:2015 (1000 Bq/kg) and is quite low compared to the activity of human bone mass (20e50 Bq/kg).[7]

Radioactivity is harmful as the majority of head and neck complications related to electron beam therapy occur in areas around metallic dental restorations. Dental alloys' high-Z metals scatter electrons from the treatment beam, creating a local dose amplification that results in mucositis and an excess dosage in the surrounding tissues. Other problems include radiation caries and osteoradionecrosis, which can be exacerbated by severe, incurable osteomyelitis. In non-cancerous tissues, latent radiation damage can range in severity from mild post-treatment pain to potentially lethal necrosis. Xerostomia, taste loss, changes in salivary chemistry and oral microbiota, glossitis, radiation caries, salivary dysfunction, dysphagia, muscle fibrosis, and necrosis are some of the oral side effects that can occur following head and neck radiation therapy. A more serious consequence is osteoradionecrosis. [8]

Enamel degradation and dentin exposure are characteristics of typical radiation caries. It mostly manifests itself on the labial surfaces of post-irradiated teeth in the cervical regions. In addition to cervical regions, teeth's incisal and occlusal edges, which are resistant to common dental decay, can also be damaged. The lesion is frequently identified by shear enamel fracture, then enamel loss that exposes the underlying dentin. It was found that the average number of decaying, missing, and filled teeth (DMFT) index in post-irradiation patients was 9.19, and the prevalence of radiation caries was found to be 28.1%. [7-9]

Radioactivity in materials

Ceramics

Glass and feldspathic ceramics are commonly used as restorative materials in dental prostheses because of their stability and aesthetic appeal. Kürkçüoğlu et al. looked at feldspathic ceramics' radioactivity. A3 shaded dentin ceramics displayed more 238U activity than A2 ceramics, according to the ceramic shades. The opaquer ceramic has the largest amount of uranium isotopes. The average radioactive concentrations of 238U, 226Ra, 232Th, and 40K in the specimens were found to be 126 ± 8 Bq kg−1, 12.7 ± 1.2 Bq kg−1, 5.6 ± 0.5 Bq kg−1, and 2855 ± 89 Bq kg−1, respectively, according to the spectrometric analyses. Every measurement fell below the ISO and EC safety norms.[1]

Resin-based Composites

In dental resin composites, the activity concentrations of 40K, 232Th, and 226Ra have been determined. The findings demonstrated that potassium had a greater radioactivity concentration and minimal activity levels compared to the other radionuclides in the resin-based composites. [7]

Zirconia

In zirconia, nuclides of the uranium, radium, and thorium series have been observed. The zirconia powder contains these contaminants. Therefore, prolonged exposure to human tissues may pose a risk. However, it was discovered that the quantity of these nuclides in the zirconia had decreased after the purifying procedure. The range of radiation values is 1-7 Bq/kg. When compared to Prettau Zirconia, the radioactivity of Vita In-Ceram and Zirkonzahn zirconia was almost three times lower than that of the other zirconia brands. According to ISO standards, the activity level was far lower than the suggested maximum of 1000 Bq/kg. [4,10]

Zirconium-oxide Implants

Zirconium based implants and its components are being used for their esthetic properties. Based on the activity assessments of ceramic implant materials, a link was found between the effective dosage and the specific activities of the nuclides of the uranium-radium and thorium series. But the estimated effective dose was below the critical dose limit of 1 mSv per year. [11]

Discussion

This review focused on available information from the literature and effects of radioactivity of dental materials used in prosthodontics. Glass and feldspathic ceramics had gross beta dose rates that were about ten times higher than the background value, while resin-based materials and alumina-based ceramics had very low beta dose rates that were comparable to those of natural tooth sample. [1,7] Majority of the papers that were referenced focused primarily on zirconia and its radioactivity, all of the zirconia specimens included radionuclides from the uranium, radium, and thorium families, suggesting the existence of this type of impurity. However, it was discovered that their levels were within the bounds. [4,10,11]

Dental professionals are advised to choose low radioactive materials and, whenever feasible, use proper protective gear in order to reduce possible radiation exposure and guarantee patient safety. When selecting and utilising dental materials in clinical practice, dentists and dental laboratories are urged to priorities patient safety and to be aware of the radioactivity of these materials. Laboratory staff should take adequate safety precautions and preventive measures because they may be exposed when the prosthesis is being finished and trimmed.

Conclusion

Backscatter radiation is a serious concern that needs to be considered when dental restorations are in the beam path. Selecting materials with lower densities is crucial since dental materials have the potential to enhance radiation to surrounding tissues. The radioactivity levels of zirconia ceramics are significantly lower than the recommended exclusion threshold, and they do not seem to pose a higher radioactive threat than the more often used feldspathic and glass ceramics. Despite the higher specific activity in zirconium oxide ceramics, the calculated effective dosage of the studied materials was within the 1 mSv/year exposure limit set for the general public. The suggested maximum limit is predicated on the 1.5-3.5 mSv normal annual dosage of cosmic radiation and naturally occurring radionuclides.

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