International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

# A Bibliometric Analysis of Radiation Protection Research in Dentistry

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**Abstract**

X-rays, a form of ionizing radiation, are routinely used in hard tissue imaging modalities in dentistry for disease diagnosis, treatment planning, and post-treatment follow-up. Although X-rays provide significant diagnostic benefits, they also have various biological effects; therefore, radiation exposure should be minimized as much as possible during imaging procedures. The aim of this study was to evaluate the scientific production performance, conceptual structure, and research trends in the field of radiation protection in dentistry through a bibliometric analysis of the relevant literature. For this purpose, a total of 471 English-language articles and reviews published between 2000 and 2025 were retrieved from the Web of Science Core Collection database and analyzed. Bibliometric analyses were performed using the bibliometrix package through R, RStudio, and Biblioshiny. Annual scientific production, keyword co-occurrence network, thematic map, and thematic evolution analyses were evaluated. The results demonstrated a marked increase in scientific production beginning in 2015, with the highest publication output recorded in 2025. Keyword analysis revealed that radiation protection, cone-beam computed tomography, dose optimization, digital imaging, radiation safety, and radiation dosimetry were the predominant research topics. Thematic evolution analysis showed that studies focusing on digital radiography and radiation exposure predominated during the earlier period, whereas research related to cone-beam computed tomography, radiation safety, and patient dose optimization became more prominent in the subsequent period.

**Keywords:** Bibliometric Analysis, Dentistry, Dose Optimization, Radiation Dose, Radiation Protection, Radiation Safety.

## 1. Introduction

Currently, radiological imaging modalities are routinely used in dentistry for disease diagnosis, treatment planning, orthodontic analyses, evaluation of adjacent anatomical structures during implant procedures, and post-treatment follow-up. While some dental imaging modalities use ionizing radiation, others do not. The imaging modalities that utilize ionizing radiation in dentistry primarily include periapical radiography, bitewing radiography, panoramic radiography, cephalometric imaging, cone-beam computed tomography, and computed tomography. These imaging modalities enable detailed evaluation of the target hard tissues and surrounding anatomical structures, thereby facilitating accurate diagnosis and appropriate treatment planning. Despite these advantages, imaging modalities that use ionizing radiation pose a risk of radiation exposure to patients, healthcare professionals, and the environment. Ionizing radiation interacts with biological tissues, leading to cellular and molecular

alterations. Some of these effects occur only when ionizing radiation exceeds a certain threshold dose, whereas others have no threshold dose and manifest in a probabilistic manner [1-5].

In recent years, the widespread use of cone-beam computed tomography in dentistry has further increased the importance of radiation protection. Although cone-beam computed tomography provides high-resolution three-dimensional images of hard tissues, allowing detailed evaluation of the structures of interest, it results in higher radiation exposure compared with two-dimensional imaging modalities [6-8]. In dentistry, the goal is to minimize radiation exposure while compromising diagnostic benefit as little as possible. To achieve this objective, the clinical necessity of each imaging modality should be carefully justified, imaging parameters should be optimized, the most appropriate imaging modality should be selected, and appropriate radiation protection measures should be implemented [2, 3, 9, 10]. Bu açıdan diş hekimliğinde radyasyondan korunma hakkında gün geçtikçe daha fazla çalışma yapılıp ilgili konudaki araştırma eğilimlerini ve mevcut durumunu değerlendirmek gittikçe zorlaşmaktadır. Bu sebeple ilgili alandaki bilimsel üretimin performansını, kavramsal yapıyı ve tematik değişimleri değerlendirmek gerekmektedir [11, 12]. Bibliometrik analiz bu eksikliklerin giderilmesi amacıyla kullanılabilen bir yöntemdir. Bu yöntem ile herhangi bir konu hakkında Annual Scientific Production, Keyword Co-occurrence Analysis, Thematic Map Analysis ve Thematic Evolution Analysisi incelenerek sonuçları nicel olarak değerlendirilebilir [13, 14].

The aim of the present study was to evaluate the current status, research trends, and temporal evolution of the literature on radiation protection in dentistry through a bibliometric analysis.

## 2. Materials and Methods

The present study was designed as a bibliometric analysis to examine research on radiation exposure in dentistry. In accordance with the nature of bibliometric studies, no human or animal subjects were involved; therefore, ethical approval was not required.

To establish the study dataset, the advanced search function of the Web of Science Core Collection (WoSCC) database was used with the following search query: (( "radiation protection" OR "radiation safety" OR ALARA OR ALADA OR ALADAIP OR "dose optimization" OR "dose reduction" ) AND (dent* OR "oral health")). Only English-language articles and reviews published between 2000 and 2025 were included. Editorial letters, conference proceedings, and publications unrelated to radiation protection in dentistry were excluded to ensure the homogeneity of the dataset.

Bibliometric analyses were performed using the bibliometrix package (version 5.3.0) through R (version 4.6.0), RStudio, and Biblioshiny. As part of the performance analysis, annual scientific production was evaluated, while the conceptual structure of the field was examined using keyword co-occurrence, thematic map analysis, and thematic evolution analysis.

The conceptual structure of the literature was investigated using network-based clustering approaches. In the resulting network, colors represented different thematic clusters, node size indicated keyword frequency, and line thickness represented the strength of co-occurrence. Only author-provided keywords were included in the keyword co-occurrence analysis. The thematic map analysis evaluated basic themes, motor themes, niche themes, and emerging/declining themes. Changes in the thematic structure over time were assessed using thematic evolution analysis, with 2010 selected as the single time-slicing year.

## 3. Results

A total of 471 publications published between 2000 and 2025 were included in this study. Evaluation of the annual scientific production in the field of radiation protection in dentistry revealed fluctuations over time; however, an overall increasing trend was observed. This increase became more pronounced after 2015. The highest scientific production was recorded in 2025 (Figure 1).

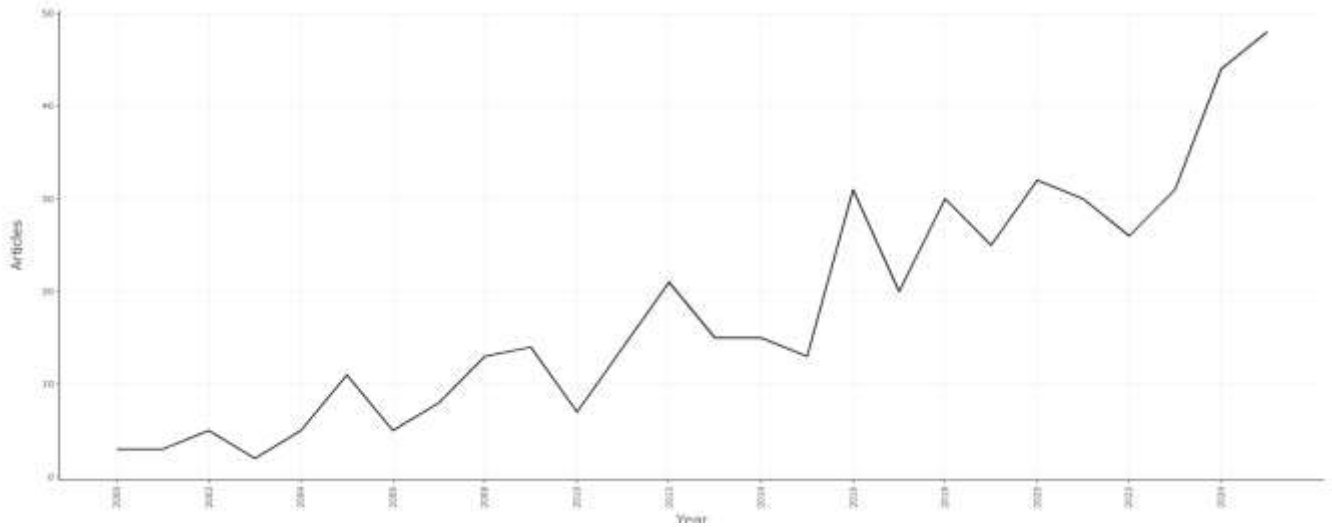


**Figure 1. Annual distribution of publications on radiation protection in dentistry.**

Keyword co-occurrence analysis identified four distinct thematic clusters. The red thematic cluster included the terms "radiation protection", "cone-beam computed tomography", "cbct", "dental radiography", "dentistry", "dose reduction", and "tomography", with "radiation protection" representing the largest node in the entire network. The green thematic cluster comprised the terms "radiography", "dental", "digital", "panoramic", "radiation dosage", and "cone beam computed tomography". The blue thematic cluster contained the terms "radiation", "protection", "dosimetry", "radiation exposure", "effective dose", "radiation safety", "dental radiology", and "dentists". The purple thematic cluster included the terms "radiology", "image quality", "radiation dose", and "dental imaging" (Figure 2).

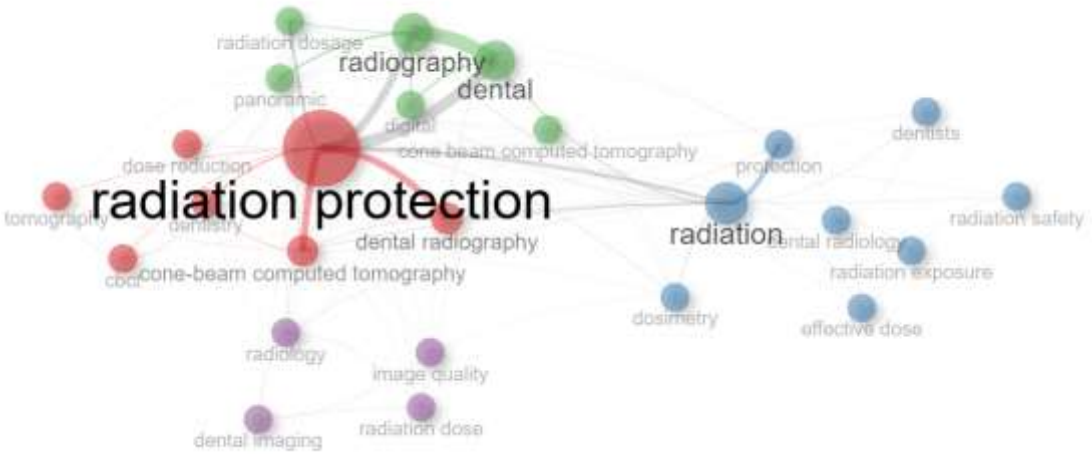


**Figure 2. Co-occurrence network of keywords in the field of radiation protection in dentistry.**

The thematic map analysis of the literature identified "ct", "dose reduction", and "dentistry" as motor themes; "exposure", "dosimetry", and "computed tomography" as basic themes; "radiation protection", "radiation", and "radiography" as niche themes; and "head" and "radiotherapy" as emerging/declining themes (Figure 3).

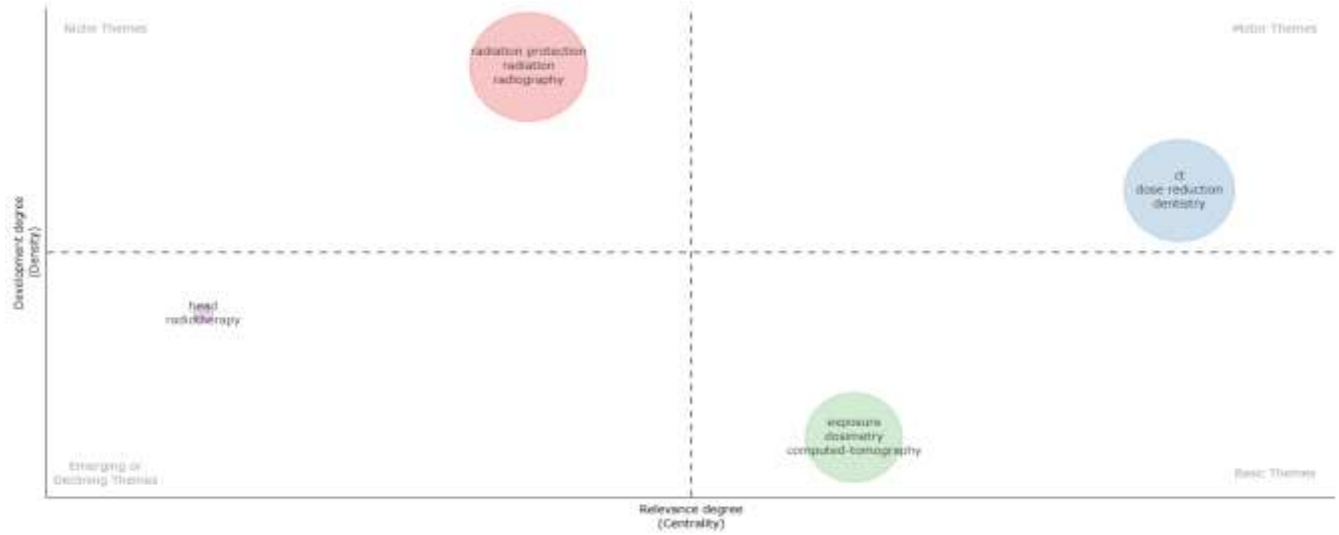


**Figure 3. Thematic map of keywords in the field of radiation protection in dentistry.**

The thematic evolution analysis of the literature on radiation protection in dentistry showed that the themes "dental digital radiography", "dose reduction", "dosimetry", and "radiation exposure" predominated during and before 2010. In contrast, the themes "radiation", "radiation dose", "radiation safety", "dental", "cbct", and "radiology" became more prominent from 2011 onwards. The themes "ct" and "radiation protection" persisted throughout both periods (Figure 4).

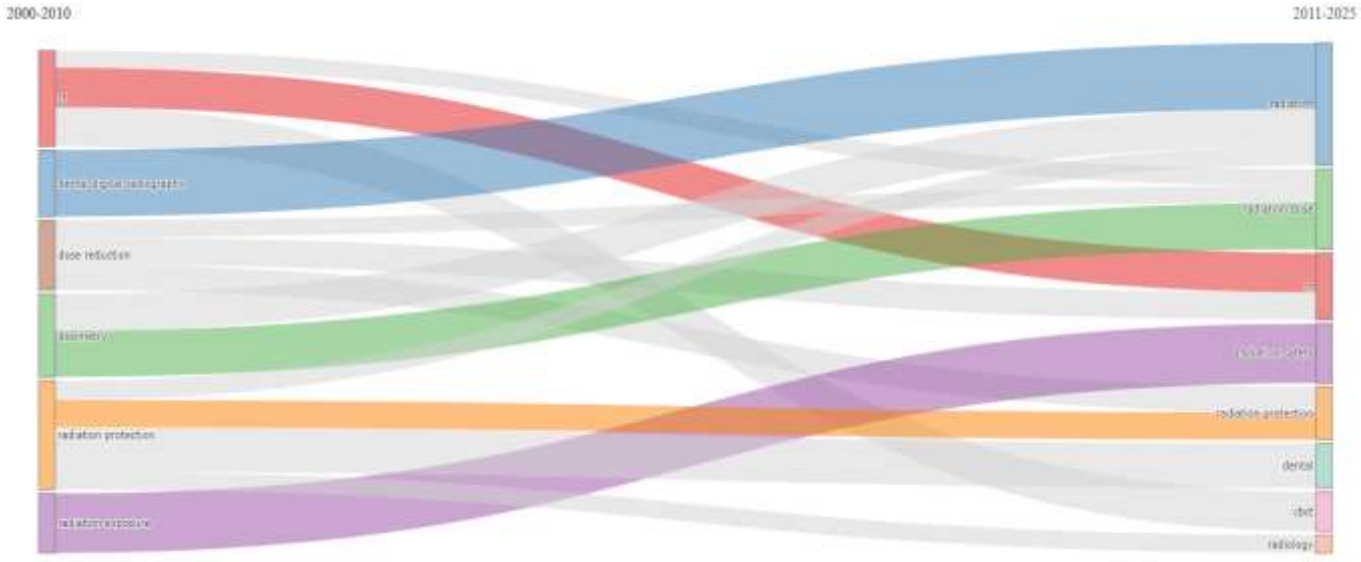


**Figure 4. Thematic evolution of keywords in the field of radiation protection in dentistry.**

## 4. Discussion

Imaging modalities are routinely used in dentistry for disease diagnosis, treatment planning, and patient follow-up. For this purpose, several hard tissue imaging modalities are employed in dental practice, including periapical radiography, bite-wing radiography, occlusal radiography, panoramic radiography, cephalometric radiography, cone-beam computed tomography, and computed tomography. These imaging modalities generate images using X-rays, a form of ionizing radiation. X-rays are high-energy electromagnetic waves that are absorbed to a greater extent by hard tissues than by soft tissues, thereby creating radiographic contrast and enabling image formation. While two-dimensional imaging modalities used in dentistry generally result in lower radiation exposure, three-dimensional imaging modalities may expose patients to higher radiation doses. Therefore, three-dimensional imaging modalities should be used only when they are diagnostically justified [1, 15-18].

Ionizing radiation is produced when X-rays remove electrons from atoms, resulting in ionization. This process may directly damage genetic material or indirectly induce cellular damage through the formation of free radicals generated by the ionization of water molecules. The resulting damage may become permanent, although complete or partial repair is also possible. The biological effects of radiation depend on the absorbed radiation dose, tissue type, cellular proliferation rate, and individual susceptibility. Radiation-induced biological effects are generally classified as deterministic or stochastic. Deterministic effects occur only above a specific threshold dose, and their severity increases with increasing radiation dose. Cataract formation and hair loss are examples of deterministic effects. Since the radiation doses used in dentistry are relatively low, these effects are rarely encountered in dental practice. In contrast, stochastic effects have no threshold dose, and their probability increases with increasing radiation exposure. Genetic alterations and cancer are examples of stochastic effects. Unnecessary radiation exposure should therefore be avoided to minimize the occurrence of these effects. To reduce the biological effects of radiation, the lowest possible radiation dose should be used without compromising diagnostic image quality. This approach should be implemented in accordance with the principles of "As Low As Reasonably Achievable (ALARA)" or "As Low As Diagnostically Acceptable Being Indication-Oriented and Patient-Specific (ALADAIP)". Accordingly, the indication for imaging should be properly justified, the imaging field should be restricted to the region of interest, radiographs should be acquired using the lowest possible radiation dose, appropriate filtration should be applied, protective equipment should be used, X-ray beam collimation should be optimized, correct patient positioning should be ensured, repeat exposures should be avoided, and personal dosimeters should be utilized. These measures provide substantial protection against the harmful effects of radiation. Although numerous studies have been conducted on radiation protection in dentistry, information regarding the research trends and conceptual structure of this field remains limited. Therefore, a bibliometric analysis of the literature on radiation protection in dentistry is needed to evaluate the scientific performance and conceptual structure of this research area [1, 19-24].

The annual scientific production in the field of radiation protection in dentistry demonstrated a marked increase over time despite fluctuations in publication output. The highest number of publications was recorded in 2025. This trend may be attributed to the widespread adoption of cone-beam computed tomography in dentistry, which exposes patients to higher radiation doses than two-dimensional imaging modalities, as well as the increasing implementation of principles such as ALARA and ALADAIP in clinical practice, leading to greater emphasis on patient dose optimization and radiation protection research [23, 25].

Keyword co-occurrence analysis identified four distinct thematic clusters. The term "radiation protection", located within the red cluster, exhibited the largest node size and the highest co-occurrence strength in the entire network. Furthermore, the presence of the terms "cone-beam computed tomography", "cbct", "dose reduction", and "tomography" within the red thematic cluster suggests that, with the widespread adoption of three-dimensional imaging modalities, research has increasingly focused on dose optimization and radiation protection [25]. The green thematic cluster included the terms "radiography", "dental", "digital", and "panoramic". This finding suggests that studies focusing on radiation dose assessment in digital radiography and panoramic radiography, which is routinely used in dental practice, constitute an important area of research. Advances in digital imaging technologies may have contributed to the development of this thematic cluster [26-29]. The blue thematic cluster included the terms "dosimetry", "effective dose", "radiation exposure", and "radiation safety". This finding suggests that the measurement of radiation dose, estimation of effective dose, occupational radiation exposure, and radiation safety have become major research focuses not only for patients but also for healthcare professionals and the environment [2, 3, 30]. The purple thematic cluster included the terms "image quality", "radiation dose", and "dental imaging", indicating that the balance between radiation dose and image quality has become an important area of research. Considering that the primary objective of contemporary imaging protocols is to achieve the lowest possible radiation dose while maintaining diagnostic accuracy, the clustering of terms related to image quality and dose optimization within the same thematic group is an expected finding [2, 23, 31].

The thematic map analysis revealed that the terms "exposure", "dosimetry", and "computed tomography" were classified as basic themes. This finding suggests that radiation exposure and radiation dose assessment in computed tomography play a central role in research on radiation protection in dentistry. The motor themes included the terms "dose reduction" and "dentistry". Consistent with the current literature, this finding indicates that research focusing on minimizing radiation dose has become a major and actively investigated topic in the field. The increasing number of studies on low-dose imaging protocols, optimization of imaging parameters, and reduction of radiation exposure while preserving diagnostic quality may explain why these keywords were identified as motor themes [23]. The presence of the terms "Radiation protection" and "radiation" within the niche themes suggests that these topics represent more specialized and well-developed areas of research. The terms "head" and "radiotherapy" were classified as emerging/declining themes. This finding may indicate that dental imaging and radiation safety in patients undergoing head and neck cancer treatment could become increasingly important research topics in the future.

The thematic evolution analysis of the literature on radiation protection in dentistry demonstrated that different research themes have predominated over time. During and before 2010, the themes "dental digital radiography", "dose reduction", "dosimetry", and "radiation exposure" were the most prominent. The emergence of these themes during the early period may be attributed to the gradual replacement of conventional film-based imaging by digital radiography and the growing emphasis on quantitatively comparing radiation exposure between these two imaging systems. From 2011 onwards, the themes "radiation dose", "radiation safety", and "cbct" became increasingly prominent, indicating that research has progressively shifted toward radiation safety and cone-beam computed tomography. This trend may be explained by the increasing academic interest in radiation protection principles such as ALARA and ALADAIP, together with the expanding use of cone-beam computed tomography in dental practice. The persistence of the theme "Ct" throughout both periods indicates that computed tomography has remained

one of the fundamental research topics in the field of radiation protection in dentistry.

The present study has several limitations. First, only English-language articles indexed in the Web of Science Core Collection (WoSCC) database were included in the dataset. Second, although bibliometric analysis provides valuable insights into the conceptual structure and research trends of a given field, it does not evaluate the clinical effectiveness or methodological quality of the included studies. Nevertheless, the widespread use of English as the primary language of scientific communication and the rigorous indexing criteria of the WoSCC database enhance the reliability of the findings presented in this study.

## 5. Conclusion

The findings of the present study demonstrate that scientific production on radiation protection in dentistry has increased substantially over time. Analysis of the conceptual structure revealed that dose optimization, radiation safety, and radiation dose assessment constitute the major research topics in this field. Research trends have evolved over time, with studies conducted during and before 2010 primarily focusing on digital radiography and radiation exposure assessment, whereas more recent research has increasingly emphasized radiation safety and patient dose optimization in relation to cone-beam computed tomography. Future bibliometric studies should incorporate multiple databases and publications in different languages to provide a more comprehensive overview of the field.

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