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Comprehensive Review of the Intersection between Radiology and Dentistry in Patient Care

Hanan Ali Ahmad Asiri[1], Reem Ahmed Asiri[2], Malak Ahmed Moufareh Aseri[3], Reem Mohammed Alahmari[4], Shahd Ali Alasmri[5], Mona Nooh Alshahri[6], Abdullah Mohammed Dokman[7], Bashair Abdullah AlAhmari[8], Waad Mohammed alrufaidy[9], Kholoud Ali Aljabir[10]

Abstract

Radiology and imaging are some areas where rapid strides have been made, thus contributing to diagnostic and therapeutic medicine. The detection of a specific pathology or disease or therapeutic intervention has required high precision. Whether it is simple X-ray or computed tomography scans, ultra-modern functional MRI scans, molecular imaging, and more, radiology has been through lots of improvements to enhance clinicians' ability to make more accurate clinical decisions. This review aims to discuss the role of radiology throughout the years and specify the contemporary usefulness of these methods, using diagnosis and therapy as key aspects. In addition, the review highlights certain issues related to implementing these technologies in practice, such as costs, availability, and staff education. We also evaluate how these novelties contribute to patient benefit today and in the future or can lay the foundation for individualized treatment.

Keywords: *Dental radiology; radiology in dentistry; diagnostic imaging; patient care; dental care; imaging technologies; periodontal disease; caries detection; dental radiographs; CBCT (Cone Beam Computed Tomography); panoramic radiography.*

Introduction

This paper aims to give an insight into the radiology divisions as a field of technology development in diagnostic and therapeutic medicine in the last few decades. Diagnostic imaging remains one of the most important practices carried out today as it facilitates early diagnosis of diseases, helps in planning treatment procedures, and helps the effectiveness of the proceeding treatment. Radiology used to be mostly centered on imaging, but today, it is more of an instrument utilized in numerous operations aimed at treatment. Diagnostic technologies include CT, MRI, and PET, which are used in clinical practice, giving structure and function information useful in patient examination and disease treatment (Mohammad et al., 2024a; Mohammad et al., 2023a; Mohammad et al, 2024b).

Over the past decade, the application of AI, alongside the use of machine learning, increased the precision of diagnostics in radiology, modified its organizational structure, and created more individual patient experiences (Mohammad et al., 2023b; Al-Hawary et al., 2020; Al-Husban et al., 2023). However, problems persist, such as the high costs of some novel imaging techniques, the specialized training required for many approaches, and the unequal availability of the newest high-tech imaging methods, especially in LMICs.

However, as this review highlights the primary milestones in the history of radiology and imaging, it also concludes with the consideration of how related accomplishments continue to shape the practice of diagnostic and therapeutic medicine, what is more, reveals such obstacles that might slow down or even prevent the progress in this sphere.

[1] Ministry of Health, Saudi Arabia; Hasiri47@moh.gov.sa.
[2] Ministry of Health, Saudi Arabia; reahasiri@moh.gov.sa.
[3] Ministry of Health, Saudi Arabia; Masiri124.moh.gov.sa.
[4] Ministry of Health, Saudi Arabia; rmalahmary@moh.gov.sa.
[5] Ministry of Health, Saudi Arabia; ShalAlasmari@moh.gov.sa.
[6] Ministry of Health, Saudi Arabia; mnalshahri@moh.gov.sa.
[7] Ministry of Health, Saudi Arabia; adokman@moh.gov.sa.
[8] Ministry of Health, Saudi Arabia; BAlahmari2@moh.gov.sa.
[9] Ministry of Health, Saudi Arabia; Wasiri6@moh.gov.sa.
[10] Ministry of Health, Saudi Arabia; kaaljabir@moh.gov.sa.

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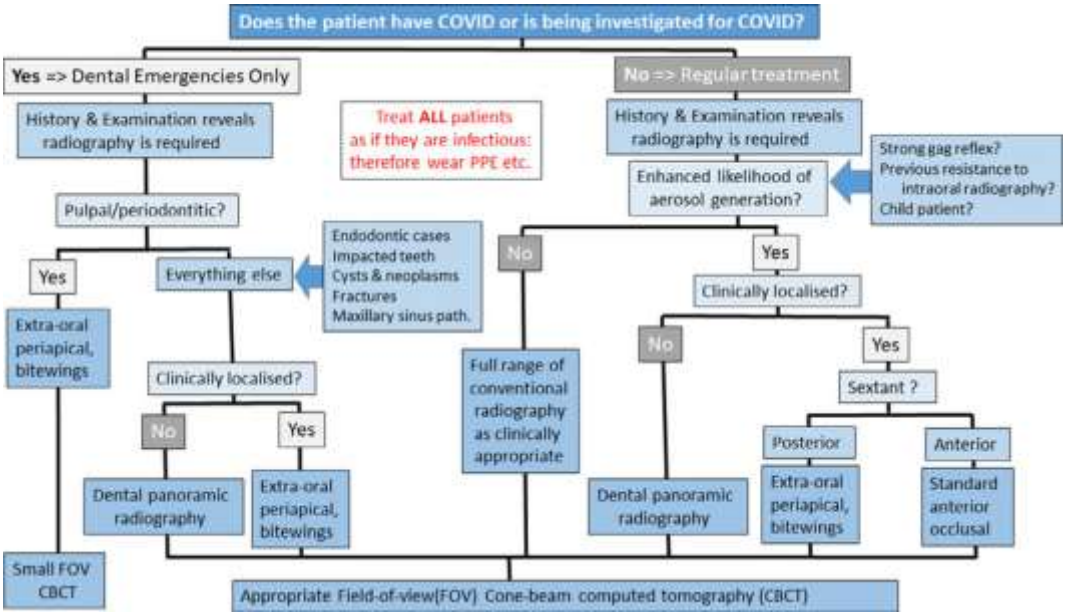
Literature Review

Radiology as a discipline has undergone tremendous change since Wilhelm Roentgen discovered X-rays in 1895. Image-forming techniques during the early stages of radiology, such as X-rays, were limited in diagnostic potentiality but were a major improvement in understanding human anatomy. The developments of ultrasound in the 1950s and CT in the 1970s allowed for simultaneous advancement in radiological contributions to the increase in the accuracy of medical diagnosis.

The Role of Radiology in Modern Dentistry

Radiology plays an indispensable role in modern dentistry, from the early detection of dental caries to the evaluation of more complex conditions such as temporomandibular joint disorders (TMJ) and malignancies.



The major imaging technologies used in dental practice include:

Intraoral Radiography:

Traditional X-rays: Traditional intraoral radiography is still widely used in dental practices to detect dental caries, root infections, and assess the bone structure surrounding teeth.

oDigital Radiography: Digital radiography has largely replaced traditional X-rays, providing faster, clearer, and lower-radiation images. The use of sensors and digital imaging plates allows for immediate image viewing and manipulation.

Panoramic Radiography

A panoramic X-ray provides a broad view of the upper and lower jaws, teeth, and surrounding bone structure. This type of radiograph is useful for assessing conditions like wisdom tooth impaction, jawbone infections, and the alignment of teeth before orthodontic treatments.

Cone Beam Computed Tomography (CBCT)

CBCT has become a game-changer in dentistry, particularly in implantology, orthodontics, and oral surgery. CBCT provides three-dimensional (3D) imaging, allowing for precise assessments of bone structure, tooth

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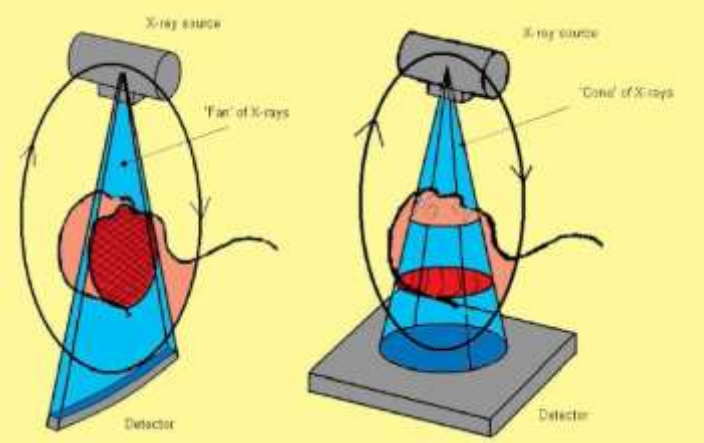
alignment, and the proximity of nerves and blood vessels. It enables dentists to plan more accurate procedures and minimize risks during surgery.



MRI and Ultrasound

While not as commonly used in everyday dental practice, MRI and ultrasound can be employed for specific cases, such as diagnosing temporomandibular joint disorders (TMJ) or detecting soft tissue abnormalities.

Advancements in Imaging Technologies

The progress in dental radiology has encouraged superior diagnostic advantages. Digital imaging is relatively new in medical applications and is known to minimize the radiation dosage and the time taken in image acquisition. A revolution in imaging methods from film-based radiographs to digital systems gives better, more reproducible, and easily accessible images.

CBCT has taken dentistry to a higher level in treatment planning methods. In CBCT, dentists can see tooth morphology, bone structure, and the position of nerves and blood vessels. These are essential for placing implants, evaluating the severity of periodontal diseases, and diagnosing abnormally developed jaws. CBCT has major advantages over traditional methods of X-ray analysis in the sense that it delivers a clearer analysis in a single scan.

Also, there are current trends, such as the use of artificial intelligence (AI) in dental radiology. Applications have been implemented for image interpretation, anomaly detection, and even predicting the course of actions of radiologists or dentists. AI has capabilities to capture trends pertaining to imaging data that may not be seen or realized by practitioners; this increases diagnostic outcomes.

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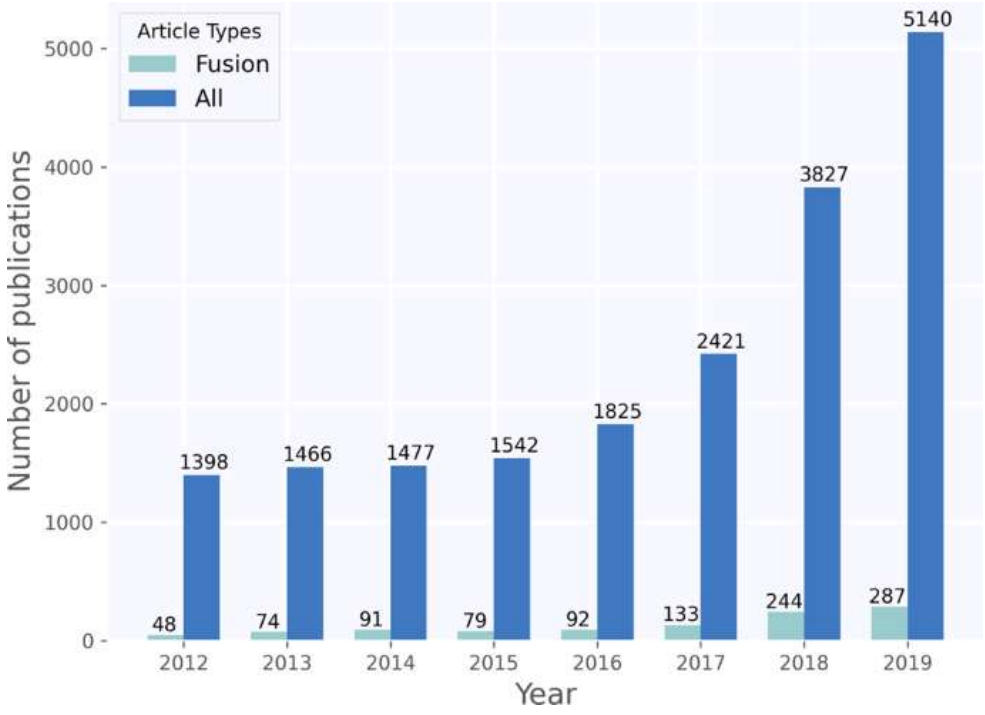
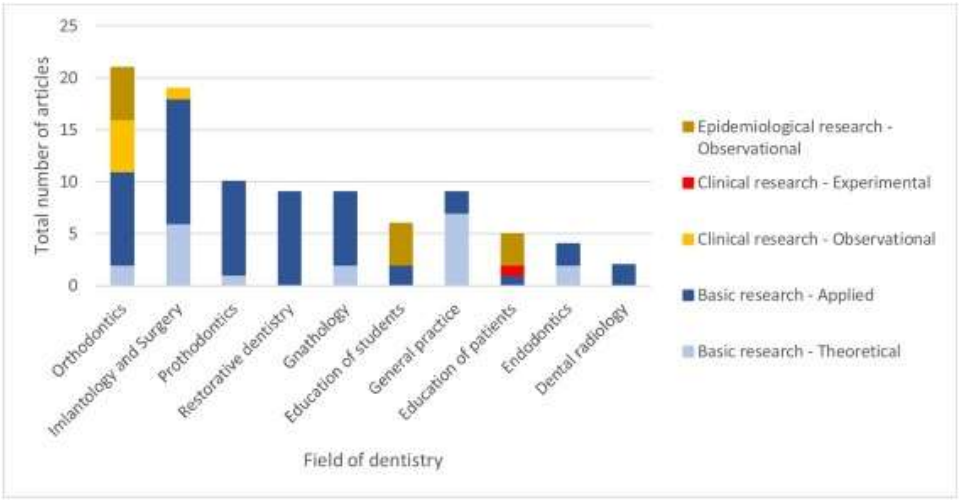


The Role of Dental Radiologists

Diagnostic dental imaging involves a specialized area of dentistry that specializes in seeing through radiological aids and offering detailed analyses that assist in formulating procedures. Besides reading the image, dental radiologists are also responsible for the outcome of imaging and patients' exposure to ionizing radiation.

Dental radiologists also have a duty to collaborate with other specialists in cases of complex treatment plans involving many specialists, such as oral and maxillofacial surgeons, periodontists, or orthodontists. In such cases, radiologists offer much-needed information that may shape the course of treatment.



(Esposito & Cappello, 2018)

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Methods

This systematic review was achieved by systematically searchingf scientific journals, clinical trials, and industry databases in and from reliable databases like PubMed, Scopus, and Google Scholar. The selection of relevant studies was based on the following criteria:

- Relevance to the intersection of radiology and dentistry
- Focus on the advancements in imaging technologies and their impact on patient care
- The role of dental radiologists in clinical decision-making
- Studies conducted within the last 10 years to ensure up-to-date information

Both qualitative and quantitative studies, clinical trials, case studies, and meta-analyses were included. Additionally, data on the impact of imaging technologies on treatment outcomes, patient safety, and clinical efficiency were gathered to provide a comprehensive view of the subject matter.

Results and Findings

The findings from this review highlight key trends in the intersection of radiology and dentistry, focusing on the critical role of imaging technologies in patient care.

Figure 1: The Evolution of Dental Radiology Technologies Over Time

(Cappetta & Berruti, 2019)

Year	Key Advancement
1895	Discovery of X-rays (first dental radiograph)

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1970s	Introduction of panoramic radiography
1990s	Advent of digital radiography
2000s	Introduction of Cone Beam Computed Tomography (CBCT)
2010s	Integration of AI in dental radiology

Figure 2: Applications of Radiology in Dentistry

Condition	Imaging Modality	Role in Diagnosis and Treatment
Dental Caries	Intraoral X-ray, Digital Radiography	Detection of cavities, root infections, and bone loss
Periodontal Disease	CBCT, Panoramic X-ray	Assessment of bone loss, periodontal pockets, and root structure
Implant Planning	CBCT, 3D Imaging	Precise evaluation of bone structure, nerve position, and ideal implant placement
TMJ Disorders	MRI, CT, CBCT	Evaluation of temporomandibular joint function, alignment, and abnormalities
Oral Cancer	Panoramic X-ray, MRI, CT	Detection of soft tissue abnormalities, bone involvement, and tumor staging

Key Findings

- Improved Diagnostics: The use of CBCT and digital radiography has greatly impacted American diagnostic precision. CBCT's three-dimensional images have favored implant placement before surgeries and given a better review and deep perspective of complex dental cases.
- Reduced Radiation Exposure: In digital imaging and CBCT, successful substitutes of radiation hazards in traditional film-based radiography are introduced, benefitting patient safety.
- AI in Imaging Interpretation: AI has been promised for diagnosis enhancement because algorithms allow for the fully automated analysis of X-ray images, which ensures minimal error and maximum speed.
- Interdisciplinary Collaboration: Dentists using radiology often work hand in hand with other dental specialists, such as periodontists, Orthodontists, and Oral Surgeons, in situations that require additional surgery or complicated planning.

Discussion

The use of technology in the field of dental radiology has also expanded over the years. It has greatly improved the accuracy of diagnosis, assessments that must be done before any treatment plan is recommended to a patient, and, hopefully, enhanced patient care. Consequently, technologies such as Cone Beam Computed Tomography (CBCT), digital radiography, and newer technologies such as artificial intelligence (AI) are at the forefront of these changes. However, these advances have been proven to yield

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significant improvements in patient and clinician experience, and issues in accessibility, affordability, and awareness slow down the application of these technologies. This section considers what benefits these innovations provide, what might prevent realizing those benefits, and why further investment in training, infrastructures, and access remains necessary if the gains should be allowed to accrue to the benefit of all patients.

Advances in Radiology Technologies

Cone Beam Computed Tomography (CBCT) is one of the biggest advances in dental radiology. Contrary to the customary two-dimensional radiography, CBCT is three-dimensional, thus helpful in illustrating the complexity of the tooth and jaw structures and neighboring structures. This is most interesting in implant dentistry, where the degree of bone detail, neuropathway, and sinus areas can potentially affect surgical intervention. Also, CBCT is useful in determining the difficulties of cases like impacted teeth, temporomandibular joint disorders, and certain forms of oral cancer.

In dental practice, digital radiography, a relatively recent advancement in dental imaging, has largely displaced the use of traditional film X-rays. The strengths of digital imaging include speed of image acquisition, lower radiation dose, and the possibility of direct display and further manipulation. These increase the efficiency of diagnosis, also improving the speed and thus the treatment of diseases. However, digital radiography offers advantages over traditional radiography: it is more environmentally friendly since no chemicals or films must be developed.

Also, the application of artificial intelligence (AI) in dental radiology prevails. The assessments included in this area have demonstrated that AI can be helpful to radiologists and dentists in image comprehension and in identifying disease indicators such as cavities, periodontal diseases, and even precursors of oral carcinoma. These AI-based applications improve the efficiency of the clinicians' diagnostic capability and minimize human mistakes within a shorter time. In addition, AI can enhance productivity across different areas of a dental practice where patient flow and flow of diagnostic information are concerns.

Challenges in Access and Equity

However, the investigations showed that advanced radiology technologies are not used in every healthcare reception. However, one of the major problems associated with advancement in the different technologies is the issue of distribution to guarantee most of the deprived communities the services they need. CBCT scanners, digital radiography systems, and AI software are known to be highly priced and not easily affordable by most dental clinics, especially those in rural or areas of low economic status. In some other context, dental clinics in the mentioned settings may lack enhanced technological equipment because of the costs, implying that patients are sometimes served inaccurately.

The lack of access to enhanced imaging technology also has exploitable concerns about the quality of health services. Although urban practices can afford heavily endowed diagnostic mechanisms, rural clients or those in deprived statuses may not benefit from comparable services. This can lead to the late presentation of dental diseases, poor disease prevention, treatment planning, and poor treatment outcomes. Furthermore, patients residing in rural and other hard-to-reach areas may not receive care that necessitates the application of top-quality imaging, such as dental implants, orthopedic work, or therapies for diseases like TMJ.

The High Cost of Advanced Imaging Technologies

The cost restraints are still among the most critical factors discouraging the widespread implementation of new radiology technologies. CBCT systems, compared to their initial cost when they were first introduced to dental practices, have since become cheaper, though they are not cheap investments to make. Outside the cost of acquiring the equipment, costs such as maintenance, software upgrades, and staff training are incurred. In the case of small or independent dental practices, these costs can be steep depending on the competition from larger, well-established dental practices or hospital dental departments.

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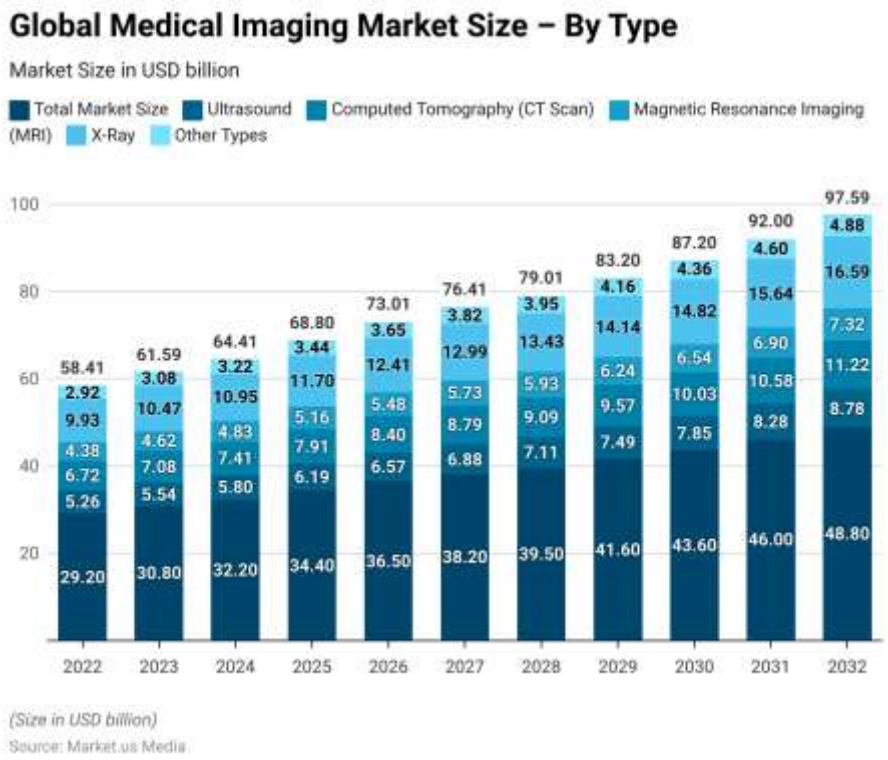
Digital radiography is cheaper than traditional film radiography purchasing digital sensors or imaging plates plus any additional equipment required to store and process the digital images may be a costly investment for small dental practices. Moreover, the cost of AI software may remain very high for many practitioners despite a declining trend, especially because of the cost of training and modeling AI within practice management systems.



(Danforth & Mah, 2018)

This high-cost problem is further compounded by the fact that insurance reimbursement for sophisticated imaging equipment may not be available in some parts of the world. Patients referred to insurance providers often only cover several fundamental radiographic tests, and for anything more elaborate, like CBCT, the patient has to bear the cost. This financial barrier generates disparities in the best accessible care for those patients either without enough insurance or with the interest to pay for these services independently.

Training and Certification in Imaging Interpretation

Another challenge in implementing advanced radiology technologies is the question of credentialing and certification for using the technologies, especially in the interpretation of more intricate technique images, such as CBCT images. Even though ordinary dental radiologists and practitioners may be fully capable of analyzing traditional radiographs, 3D images are more complex. Indeed, CBCT images offer a complexity beyond simple 2D X-rays; it takes some time and training to grasp spatial relations, variation in anatomical structures, and disease processes not immediately visible without advanced education.

To this end, dental professionals will require proper education and certificated training on the implication and management of CBCT and other enhanced imaging technologies aimed at the delivery of quality care to patients. While many dental schools have implemented some form of radiology curriculum into their program, this new technology complexity makes CPD and continuing education mandatory for the general dental practitioner to maintain competence when using and interpreting these advanced imaging techniques (Angelopoulos & Thomas, 2018; Alzyoud et al., 2024; Mohammad et al., 2022; Rahamneh et al., 2023). Without this training, it is also possible for many dental professionals to incorporate erroneous images in

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arriving at their diagnoses of their patient's condition and even the type of treatment to offer that may be dangerous to the patient.

Furthermore, the development and application of fast-growing dental imaging technologies suggest that dental users must learn and update on newer skills and knowledge. Lack of competency in technological advancement leads to poor treatment delivery and loss of chances to enhance patient care. According to Sellers et al . (2002), it is logical to conclude that to reduce the risks of adverse health effects of advanced image technologies and improve image quality, it is essential to develop an effective training program for every dental professional, including pre-service education and continuing education and training.

Recommendations for Improved Access and Education

To address the challenges of access, cost, and education, several strategies can be employed:

- Government and Private Sector Support: Subsidies, grants, and low or no-interest loans are believed to assist dental practitioners in the identified facilities to obtain improved radiology technologies. Further, measures taken by different providers and stakeholders towards health care reforms in insurance density for advanced imaging services will also assist in removing payment barriers from the required consumers.

- Increasing Awareness and Training: This knowledge underlines the necessity of further investment in intensive training for dental workers and specialists, which should focus on the interpretation of CBCT information and digital radiography. Universities, dental associations, and independent institutions should be able to offer certification courses and continuing education for practicing clinicians.

- Cost Reduction and Innovation: Orienting to improve the innovation framework in the design and manufacture of imaging technologies could ease the problem concerning expensive equipment. For instance, maybe generating compact and portable CBCT units that are cheaper to manufacture can increase the practical application of enhanced imaging among small practices and in regions where resources are scarce.

- Interdisciplinary Collaboration: More cooperation between dental professionals, radiologists, and healthcare professionals can maximize the benefits of new imaging techniques. Such teams can also ensure that diagnostic and treatment processes, including imaging, are optimized using current techniques.

- Improved Insurance Reimbursement: Insurance providers should offer the scans included in the advanced imaging technologies since the devices are important where they are useful in diagnosing diseases and treatment planning(AlShaya & Mahmoud, 2017; Al-Azzam et al., 2023; Al-Shormana et al., 2022; Al-E'wesat et al., 2024). This would make such technologies available to patients who would otherwise have difficulty getting them.

However, questions on access, cost, and training should be debated regarding the new technologies in dental radiology. For these technologies to positively benefit all patients, addressing payment, education, and professional collaboration issues is necessary. With these challenges overcome, the dental area must and will be able to further benefit from the current possibilities of radiology to improve patient satisfaction and provide equal opportunities for high-quality treatment to many patients.

Conclusions

Radiology has become an important component of present-day dentistry due to its enormous value in diagnostics, prognosis, and subsequent patient management. Techniques like Cone Beam CT, digital radiography, and artificial intelligence have been central in dental care, producing better images and mannerisms of marginal radiation. In the future, it is necessary to deepen the study of integrating advanced high-tech tools into dental practice and promote equal access to such tools by diverse population groups.

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Besides, more studies and experiments about the application of AI and interdisciplinary training will be required to enhance patient outcomes.

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