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LETTERS TO THE EDITOR:

The Role of Simulation Technologies in Advancing Dental Radiology Education

El papel de las tecnologías de simulación en el avance de la educación en radiología dental

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Dear Editor,

The rapid digitalization of dental imaging technologies has significantly impacted the training of x-ray technicians (1). Traditional methods, which rely heavily on direct patient interaction, are increasingly limited in their ability to ensure both effective skill acquisition and patient safety. With the growing complexity of digital radiographic systems, there is a need to explore innovative methods to bridge the gap between current educational practices and modern technological advancements. Simulation-based training presents a promising solution, though its role in dental radiology education remains underexplored.

Several types of simulation technologies have emerged in recent years to address these challenges (2). These include physical simulators, computer-based systems, and virtual/augmented reality platforms. Each offers unique advantages and limitations that could complement existing training methodologies.

Physical simulators (phantom heads or jaws) are life-sized anatomical models designed for hands-on practice in dental radiology. They replicate the human skull, jaw, and oral cavity, using materials that mimic the radiopacity and density of natural bone and soft tissues. Some models feature replaceable radiopaque teeth and soft tissue analogs, which enable trainees to practice X-ray positioning, sensor

placement, and angulation techniques under near-clinical conditions (3). Certain high-fidelity models include articulating jaws and interchangeable components, offering different anatomical variations for more diverse practice scenarios.

Computer-based simulation platforms create interactive digital environments where trainees can manipulate virtual patient models and adjust exposure parameters in real-time. These systems typically offer high-resolution 3D imaging and software that replicates radiographic procedures accurately (4). They provide immediate feedback on positioning errors, image quality, and radiation dosage, aiding users in refining their technical skills. Some platforms incorporate artificial intelligence to personalize learning experiences, adjusting based on user performance.

Virtual and Augmented Reality (VR/AR) simulation technologies deliver immersive training experiences by enabling users to interact with virtual patients and radiographic equipment in a 3D space (5). VR simulations replicate entire clinical environments, allowing trainees to practice complex procedures while enhancing spatial awareness and motor coordination. AR overlays digital images onto physical objects, enabling real-time visualization of internal anatomical structures and radiation pathways. These systems guide trainees step-by-step through imaging protocols with virtual markers and interactive prompts.

Each of these simulation methods has its own set of strengths and weaknesses, which we have summarized from our own experience and the limited available literature in the Table 1.

While these technologies show considerable promise, further research is needed to evaluate their effectiveness in the context of dental radiology training. Understanding their impact on skill development, clinical decision-making, and patient safety is essential for determining their place in modern educational programs. Given the high costs associated with some of these technologies, it is also important to explore the feasibility of their widespread adoption, particularly for institutions with limited financial resources.

This letter aims to foster ongoing discussions and further scientific investigation into the role of simulation in dental radiology education. By examining the benefits and challenges of these methods, we can work toward a more informed understanding of how they can enhance the training of x-ray technicians, ultimately improving the quality of care provided in dental practices.

Table 1. Applications, advantages, and limitations of different simulation methods in dental radiography training.

Simulator type	Application	Advantages	Limitations
Physical simulators (phantom heads or jaws)	Patient positioning Sensor placement X-ray tube alignment Intraoral and extraoral techniques	Realistic anatomical structures Repeated practice in a controlled environment Radiation-free Develops motor skills Cost-effective	Limited anatomical variability Cannot simulate patient movement or discomfort
Computer-based simulations	Patient positioning Sensor placement X-ray tube alignment Exposure settings Image processing Radiation safety	Radiation-free Immediate feedback and performance tracking Wide range of anatomical variations Cost-effective over time	No hands-on practice with real equipment Requires high-quality software and hardware Cannot simulate patient movement or discomfort
Virtual and Aug-mented Reality (VR/AR) Simula-tions	Patient positioning Sensor placement X-ray tube alignment Exposure settings Equipment operation	Radiation-free Enhances spatial awareness Real-time error correction	High financial and technological investment Cannot simulate patient movement or discomfort

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