Integration Of Photogrammetry In Dental Education Curriculum: Potentials And Challenges

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ABSTRACT

Background: *Photogrammetry allows the creation of accurate 3D models of tooth structure and the oral cavity, offering improved anatomical visualization and a deeper understanding of complex structures in dentistry. This study aims to explore the integration of photogrammetry in the dental education curriculum, with a particular focus on the potential benefits and challenges faced*
Method: *Researchers used a qualitative approach with the main focus on scoping review. This technique makes a significant contribution to enhancing case-based learning and clinical skills development, by enriching students' practical and collaborative experiences.*
Result: *Despite its enormous potential, the application of photogrammetry in dental education faces challenges, including the cost of hardware and software, as well as the need for comprehensive training for educators and students.*
Conclusion: *This study recommends continued integration of photogrammetry in dental curricula, with a focus on developing resources and training to maximize its potential.*

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INTRODUCTION

In the rapidly evolving digital era, the field of dental education faces challenges to maintain its relevance and effectiveness. The need for innovative technological integration has become crucial, particularly in enriching teaching methods and clinical practices. Technologies such as photogrammetry have the potential to transform traditional paradigms in dental education, moving from physical models and direct demonstrations to a more interactive and visual approach. Photogrammetry, capable of generating accurate 3D digital models of dental structures and oral cavities, opens opportunities for deeper and impactful learning approaches.[1] This development is pivotal given the limitations of conventional learning models in addressing diverse clinical cases and anatomical variations. [2,3] Therefore, the application of photogrammetry not only promises enhancements in educational quality but also brings dental education closer to the digital age, where technology-based learning is increasingly relevant and essential. [4]

Photogrammetry, a technique within the digital realm, redefines how we understand and depict real-world objects. In the context of dental education, this technique allows for the creation of highly detailed and accurate 3D models of teeth and oral tissues. By using a series of photographs from different angles, photogrammetry produces digital models that can be rotated, zoomed in, and analyzed with unparalleled depth compared to traditional physical models. These advantages not only enrich the visual experience for students but also provide deeper insights into complex anatomical structures and variations in dental medicine. [5,6] Furthermore, the ability to simulate various clinical conditions and cases in a virtual environment offers a unique opportunity for adaptive and responsive learning tailored to individual student needs. Thus, photogrammetry not only strengthens the theoretical aspects of dental education but also enhances its practical dimensions through realistic and interactive simulations.[7]

Integrating photogrammetry into the dental curriculum offers several benefits that significantly enhance educational quality. One of the main advantages is improved visualization and understanding of complex anatomical structures. Students can gain a more profound and intuitive understanding of dental anatomy and oral tissues through interactive 3D models. This is particularly beneficial in overcoming the limitations of physical learning models, which often fail to demonstrate real-world anatomical variations. Moreover, photogrammetry enables the simulation of various clinical cases, enriching learning experiences with exposure to diverse scenarios that may not often be encountered in clinical practice. This not only enhances diagnostic and treatment skills but also prepares students to face real-world challenges in their careers. Furthermore, the use of this technology supports both self-directed and collaborative learning, allowing students to learn at their own pace and collaborate in virtual environments. [2,3] Thus, photogrammetry not only enhances the cognitive aspects of learning but also enriches students' practical and collaborative experiences in dental education. [1]

This research aims to comprehensively investigate how photogrammetry can be integrated into the dental education curriculum, focusing specifically on its potential benefits and challenges. Through in-depth analysis, the study seeks to map out the advantages that photogrammetry can offer in enhancing students' understanding and practical skills in dental medicine. Additionally, the research aims to identify and evaluate challenges in implementing this technology, including cost considerations, training needs, and integration with existing curricula and teaching methods. The ultimate goal is to provide strategic recommendations that can assist dental education institutions in effectively

adopting photogrammetry while contributing to the literature on the use of innovative technology in dental education. Therefore, this research is not only academically relevant but also crucial in a practical context for the future development of dental education. [2,3,1]

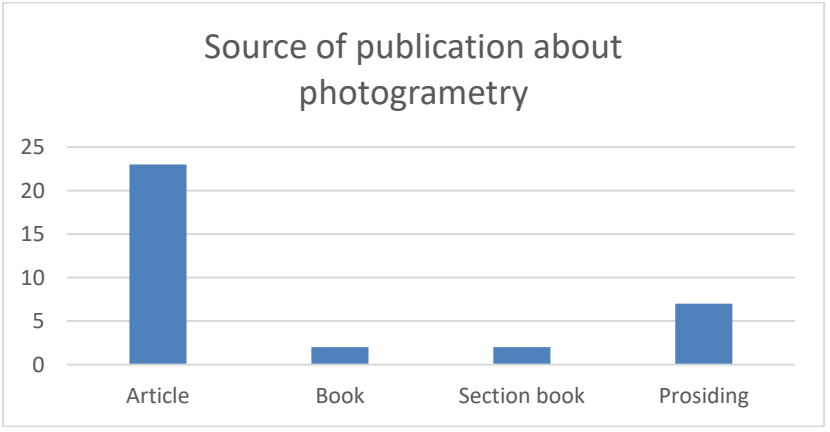
RESEARCH METHODS

The author employed a qualitative approach with a primary focus on literature review. This process involved conducting a comprehensive search for relevant theories and references related to the research topic. Randolph (2009) outlines the steps involved in conducting a literature review, including formulating the problem, collecting and evaluating relevant literature sources, analyzing and interpreting the literature, and presenting findings publicly. [8] This review relied on the analysis and interpretation of literature obtained from various international English-language publications such as journal articles, book chapters, books, patents, and proceedings published within the last decade. Search strings used included 'photogrammetry OR digital technology', 'photogrammetry OR digital technology AND dentistry', 'photogrammetry OR digital technology AND dental education', 'potential and challenges AND photogrammetry OR digital technology AND dental education', and 'curriculum integration and development in medical education'. Information extracted from diverse literature sources was then synthesized to formulate conclusions and new ideas.

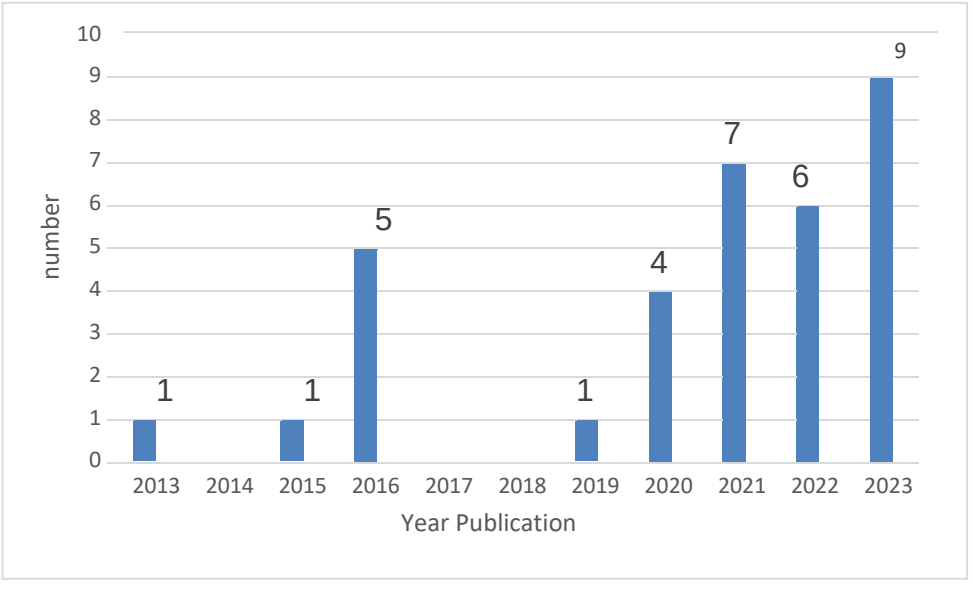
RESEARCH FINDINGS

The search yielded 34 publications including articles, books, book chapters, and proceedings published within the last 10 years, as depicted in Tables 1 and 2 below:

Table1. Number and Resource



Tabel 2. Publication per Year



Photogrammetry in Dental Medicine

Photogrammetry is a technique used to obtain reliable information about physical objects and environments through the recording, measurement, and interpretation of photographic images. It involves using photos taken from different angles and positions to determine coordinates and three-dimensional distances. [9] The fundamental principles of photogrammetry include the use of central projection and collinearity equations to create mathematical models for 3D measurements. [10] Photogrammetry finds applications in various fields such as archaeology, architecture, topography, and engineering due to its ease of application, cost-effectiveness, and high-quality results.[11] In the field of dental medicine, photogrammetry is used to create accurate 3D models of tooth structures and oral cavities and has shown promising results in obtaining three-dimensional models of the head, jaws, alveolar processes, teeth, as well as reproducing centric occlusion and jaw articulation relationships. [12,13] This technique allows dental professionals to gain a deeper understanding of patient anatomy, which is valuable for both diagnosis and treatment. [14,15]

DISCUSSION

In the field of dentistry, Photogrammetry is utilized to create accurate 3D models of dental structures and the oral cavity. [16,17] It has shown promising results in generating three-dimensional models of the head, jaws, alveolar processes, teeth, as well as reproducing centric occlusion and articulation relationships of the jaws. This technique enables dental professionals to gain a deeper understanding of patient anatomy, which is highly beneficial for both diagnosis and treatment. For instance, in a study by Reem Al-Tameemi et al. (2023), photogrammetry was employed to reconstruct 3D digital models from conventional dental models as an alternative to conventional scanning, demonstrating the potential applications of this technique in dentistry. [18]

In the context of implantology, photogrammetry offers possibilities to enhance accuracy and efficiency in the process. Mostafa Omran Hussein (2021), in his review, explores the use of photogrammetry technology in dental implantology, highlighting its capability to improve treatment outcomes by utilizing accurate 3D models for planning and executing implants. [19] Other research, conducted by Emanuele Clozza (2023), describes the integration of photogrammetry with intraoral scanning to create implant-supported dental prostheses. This technique promises efficiency in delivering both temporary and definitive prostheses to edentulous patients, emphasizing photogrammetry's potential to streamline clinical workflows and enhance treatment outcomes. [20]

The Potential Integration of Photogrammetry in the Dental Education Curriculum: Photogrammetry, a technology enabling the creation of accurate 3D models from physical objects through image capture, holds significant potential for integration into dental education. Here are several key aspects illustrating its potential:

Enhanced Visualization of Anatomy: Photogrammetry enables the creation of precise 3D models of teeth and the oral cavity, significantly contributing to dental education. This technique facilitates the visualization of complex anatomical structures in a more intuitive and interactive manner, aiding students in better understanding anatomical details. Barkha Bansal and Pratik Kariya (2023) in their study "Three-dimensional printing: A tool for redefining pediatric dental practice" explain how 3D printing technology, akin to photogrammetry, is used to redefine pediatric dental practices by providing improved visualization and more accurate anatomical modeling. [21]

***Enhancing Anatomy Understanding through 3D Visualization*:** The use of 3D visualization technology, exemplified by photogrammetry, enhances the learning process in dentistry by allowing students to explore anatomical structures virtually. This is particularly crucial in dental morphology education, where a profound

understanding of tooth form and structure is essential. T. Vagg et al. (2023) in their study "Visualizing Anatomy in Dental Morphology Education" underscore the importance of anatomical visualization in dental morphology education, demonstrating how visualization technology aids in better comprehension of dental and oral cavity structures. [22]

Photogrammetry in Case-Based Learning: This technology enables the creation of accurate 3D models of teeth and the oral cavity, providing students with the opportunity to analyze real-life cases virtually. This enhances their learning experience, allowing them to tackle complex and realistic cases. For example, in the article "Enhancing Student Learning of Removable Prosthodontics Using the Latest Advancements in Virtual 3D Modeling" by Ahmed Mahrous and G. Schneider (2019), the use of 3D model software in prosthodontic education demonstrates how 3D models, akin to photogrammetry, can enhance student understanding and learning. In the study "Virtual Fossils for Widening Geoeducation Approaches" by Senay Ozkaya de Juanas et al. (2023), the use of virtual fossils created through photogrammetry illustrates how 3D visualization can enrich case-based learning. [23]

Improved Clinical Skills Training: Photogrammetry plays a key role in developing clinical skills among dental students, particularly through the use of digital technology and 3D models. Shivani Kohli and S. Bhatia, in their article "The Need for Dental Digital Photography Education" (2016), underscore the importance of digital photography in dental education, including its role in enhancing patient records and student learning.1 A study by Arian B. Deutsch, titled "How Digital Technologies Enhance Telescopic and Conical Clinical Case Workflows" (2022), discusses the impact of digital technologies, including photogrammetry, in dental prosthetics fabrication, highlighting its utility in training and clinical practice.2 Furthermore, research by Giuliano O. Giacomini et al. (2022), titled "3D Printed Model for Preclinical Training in Oral Radiology," outlines the use of 3D printed models in preclinical training for intraoral radiography techniques, illustrating the potential of photogrammetry in dental education.[24] In the field of conservative dentistry, M. Richter et al. (2021) in their article "3D Printed versus Commercial Models in Undergraduate Conservative Dentistry Training," compare 3D printed models with commercial models, demonstrating the effectiveness of 3D models in dental clinical training and education.[25]

Enhanced Interactive and Engaging Learning: This technology provides a more interactive and engaging learning approach for students, which can foster deeper engagement and motivation in learning. Poyade et al. in their study titled "Toward the Development of an Accurate 3D Human Body Model Implemented in a Real-Time, Interactive Application to Enhance Anatomy Teaching" (2015), explore the effectiveness of 3D human body models in anatomy education. This study highlights the crucial role of photogrammetry in creating interactive 3D anatomy models, enhancing the learning experience for dental students.[3] Meanwhile, in the article "Digital technology as a tool for academic tutoring in dental school during the COVID-19 pandemic" (2021), Bianca Maria de Melo Costa et al. discuss the implementation of digital technology, including photogrammetry, in remote education during the COVID-19 pandemic. This article explains how interactive technology aids in the learning process.[26] T. Gredes et al. in "Survey of student attitudes toward digital technology in practical technical dental education using the AR-Demonstrator-App." (2021), investigate the utilization of augmented reality (AR) applications in practical dental education. This research connects the use of AR with principles of photogrammetry to create a more engaging educational model.[27] Finally, Jung-Chul Park et al. in "Innovative digital tools for new trends in teaching and assessment methods in medical and dental education" (2021),

evaluate various digital tools in medical and dental education. They underscore how photogrammetry and other digital technologies can make learning more interactive and engaging.[28]

Preparation for the Digital Era: In the current digital era, mastery of technologies such as photogrammetry is crucial. The integration of this technology in dental education prepares graduates to work in clinical environments increasingly reliant on advanced technology. Djendo Djendov and G. Georgieva, in their article "Advantages and disadvantages of digital technologies in dental medicine education" (2021), examine the use of digital technology in dental education, with a specific focus on photogrammetry. They discuss how this technology can enrich the learning experience and equip students with the necessary skills for the digital era in dentistry.[29] Yoshiki Ishida et al. in the study "Current Implementation of Digital Dentistry for Removable Prosthodontics in US Dental Schools" (2022), investigate the implementation of digital technology in US dental schools. They emphasize the importance of integrating digital technology into the curriculum to meet future challenges.[30] "The Status of Digital Dental Technology Implementation in the Saudi Dental Schools' Curriculum: A National Cross-Sectional Survey for Healthcare Digitization" by Hayam A. Alfallaj et al. (2022) reviews the adoption of digital technology in Saudi Arabian dental schools. This study underscores the urgent need to integrate digital technology into dental education to support the shift towards digital healthcare.[31] In "Strategic Analysis in the Application of Digital Technology in Dental Practice" (2023), Nora Lelyana discusses the role of digital technology in dental practice, highlighting its impact on efficiency and benefits. This research underscores the importance of digital technology, including photogrammetry, in enhancing the quality of dental education and practice.[32] Finally, C. Dooley et al. in "Digital Participatory Pedagogy: Digital Participation as a Method for Technology Integration in Curriculum" (2016), explore methods for integrating digital technology in education. They demonstrate that digital participation can strengthen the learning experience and help prepare students for the future in the digital era.[33]

Challenges and Constraints in Implementation: Photogrammetry in dental education faces various significant challenges and constraints. L. Jahangiri et al., in "Understanding the complexities of digital dentistry integration in high-volume dental institutions" (2020), reveal difficulties in integrating digital technologies, including photogrammetry, into large dental institutions. Challenges include limited resources, funding constraints, and the need for comprehensive training for faculty and students.[34] In the study "Current Implementation of Digital Dentistry for Removable Prosthodontics in US Dental Schools" by Yoshiki Ishida et al. (2022), the focus is on the implementation of digital technology, akin to photogrammetry, in removable prosthodontics in US dental schools. Challenges encountered include funding limitations, time constraints, resource availability, and faculty readiness.[30] Meanwhile, "Going electronic: an Epic move" by Jaspreet Virdee et al. (2022) explores the transition to electronic dental practices. While not directly related to photogrammetry, challenges such as change management, training needs, and adaptation to new technologies addressed in this study are also relevant and crucial to consider in the context of photogrammetry implementation.[35]

The Future of Photogrammetry in Dental Education: Photogrammetry holds significant potential for advancing dental education, particularly in enriching learning experiences through more interactive and innovative methods. Jae Il Lee, in his article "Dental education now and in the future" (2023), highlights how technology has been integrated into dental education to enhance teaching and learning. Aspects such as student training in virtual reality simulations, digital imaging, 3D printing, and intraoral scanning have made the learning process more interactive and

comprehensive, enhancing diagnostic capabilities and patient management.[36] T. Wiedemann, in his study "Evolution or Revolution: Is Robotics the New Age Digital Shift in Dental Education?" (2023), examines how technology influences the evolution of dentistry, focusing on radiology, biomaterials, scanning, and milling technologies. This opens new opportunities for more efficient treatments and predictable outcomes.[37] S. Bencharit et al., in "Recent Advancements in CAD/CAM Same-Day Dentistry in Practice and Education" (2021), evaluate recent developments in CAD/CAM dentistry, highlighting the digital applications in educational programs and practice. They discuss advancements in software and materials associated with CAD/CAM dentistry.[38] Finally, Naseemoon Shaik et al. in "Digital revolution" (2022), provide an overview of digitalization in dentistry, the technologies involved, their future potential, and the impact of the COVID-19 pandemic on the field. This article emphasizes the crucial role of research in advancing digital dental technology.[39]

CONCLUSION

Photogrammetry, a technique enabling accurate 3D model creation of physical objects through image capture, offers significant potential in dental education. This technique supports more intuitive and interactive anatomical visualization, aiding students in better understanding anatomical structures. Furthermore, photogrammetry allows for the creation of precise 3D models of teeth and the oral cavity, providing opportunities for virtual analysis of real-life cases, thereby enhancing the learning experience. In the context of clinical skills, photogrammetry plays a crucial role in developing students' capabilities, including the use of digital technology and models. This technology also provides more interactive and engaging learning methods, strengthening the learning experience. The integration of photogrammetry in dental education also prepares graduates to work in clinical environments increasingly reliant on digital technology. However, the implementation of photogrammetry in dental education faces challenges, including limited resources, funding constraints, and the need for comprehensive training for both faculty and students. Despite these challenges, the future of photogrammetry in dental education appears promising, with the potential to advance education through more interactive and innovative methods.

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