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A RETROSPECTIVE CLINICAL AUDIT OF QUALITY OF INDIRECT DIGITAL INTRAORAL RADIOGRAPHS TAKEN BY STUDENTS AND DENTAL ASSISTANTS IN AN UNDERGRADUATE DENTAL CLINIC

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Abstract

Background: Intraoral radiographs are essential diagnostic tools in dentistry. Ensuring their quality is crucial for accurate diagnosis and treatment planning. This study compared the quality of radiographs produced by undergraduate dental students and qualified dental assistants to identify common errors and assess improvements following feedback and interventions. Methods: This retrospective, observational study compared the quality of digital bitewing and periapical radiographs taken by students and assistants across two audit cycles, with feedback provided between cycles. The radiographs were assessed using a modified quality assessment scale based on the Faculty of General Dental Practice (FGDP, UK) guidelines. Data were collected from the radiology imaging software, and a total of 100 intraoral digital radiographs were analyzed for each group in both cycles. Results: Initially, radiographs from both groups had issues, primarily positioning errors. After providing feedback and additional training, significant improvements were observed from Cycle 1 to Cycle 2. Dental assistants had a higher percentage of acceptable periapical radiographs, while students excelled in bitewing radiographs. Both groups demonstrated marked improvements, reflecting the effectiveness of the interventions. Conclusions: Continuous training, feedback, and quality assurance measures are vital for improving radiograph quality. A multifaceted approach, including updated equipment and adherence to quality control protocols, can significantly enhance patient care. The study highlights the importance of regular calibration and training for dental professionals to maintain high standards in radiographic practices. Further research is recommended to identify additional strategies for improving radiographic quality.

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Introduction

The concept of medical audits has evolved significantly since its early beginnings in human history. The first recorded attempt at conducting a medical audit dates back to ancient Egypt, where the practice of medicine was regulated by a strict code of ethics (Nunn, 2002). These early audits were a means of evaluating the medical practices of physicians and ensuring that they adhered to the established guidelines for patient care. The objective was to maintain a high standard of medical care, and this underlying principle remains at the core of modern medical audits. Today, medical audits have expanded to encompass a wide range of healthcare disciplines, including radiology and dental radiography.

Radiology is a critical component of modern healthcare, and maintaining high standards in image quality and diagnostic accuracy is vital for patient care. Medical audits in radiology serve to evaluate the performance of radiologic procedures, identify areas for improvement, and ensure that radiation exposure is kept to a minimum while maintaining diagnostic quality. In dental radiography, audits can assess the quality of intraoral radiographs taken by dental professionals and evaluate their adherence to established guidelines and protocols. By conducting regular audits, dental professionals can identify potential shortcomings in their radiographic techniques and implement strategies to enhance the overall quality and safety of dental radiographs, ultimately improving patient care and outcomes.

Quality assurance in radiology is essential for ensuring consistently high-quality images while minimizing the exposure of patients and workers to radiation (Guide, 2018; Benavides et al., 2024). A radiographic audit is a quality assurance process that evaluates the diagnostic quality of radiographs taken by dentists, students, and dental assistants. In many modern hospitals and clinics, radiographers supervise all dental professionals, including students and dental assistants. However, our study focuses on settings where dental professionals may operate with limited supervision from radiographers. By identifying areas for improvement, appropriate protocols can be implemented to reduce the number of repeat radiographs and minimize radiation exposure in accordance with the As Low As Reasonably Practicable (ALARP) principle (Greenwood, 2013).

Various types of clinical audits exist for radiographers, including national, local, retrospective, prospective, compliance, and improvement audits, among others. In this research, we conducted a retrospective audit due to its advantage of not disrupting normal radiography clinical activity. This is particularly beneficial when managing high patient workloads, although retrospective audits may be limited by incomplete data (European Society of Radiology, 2010).

Our study aimed to compare the quality of digital intra-oral radiographs taken by undergraduate students and dental assistants. This comparison is essential because both groups play crucial roles in dental clinics, yet they possess different levels of experience and training. Understanding these differences can help in identifying specific training needs and improving overall radiograph quality. This study is, to the best of our knowledge, the first to make such a comparison and apply the updated two-point quality rating scale for radiographs.

The primary goals of this retrospective audit were to assess and audit the quality of digital intraoral bitewing (BW) and periapical (PA) radiographs taken by both students and dental assistants in an undergraduate dental setting, and to evaluate the potential improvements in radiograph quality following remedial actions and completion of the audit cycle with a repeated audit. To accomplish these goals, the objectives of this study included establishing good practice standards and criteria, implementing necessary modifications, reducing the number of repeat radiographs and associated costs, identifying and addressing sources of error, ensuring patient radiation exposure adheres to the ALARP principle, and conducting regular and periodic audit repetitions to maintain and enhance radiographic quality.

Methods

This study is a retrospective, observational audit comparing the quality of digital intra-oral radiographs taken by undergraduate students and qualified dental assistants, conducted over two audit cycles within an undergraduate dental setting. Upon obtaining approval from the Ethics, Research, and Innovation Committee, the principal investigator

underwent training and calibration. A pilot study consisting of ten bitewing (BW) and ten periapical (PA) radiographs was conducted for planning and validation purposes. All digital radiographs were acquired using phosphor storage plate (PSP) sensors and the paralleling technique with receptor holders. Data were collected from the radiology imaging software, with radiographs being randomly selected from all patients treated in the clinic.

Both students and dental assistants took the radiographs. The study population consisted of patients treated in our undergraduate dental clinic. Each audit cycle included a sample of 50 BW and 50 PA radiographs, totaling 100 intra-oral digital radiographs for both students and dental assistants. The first cycle's radiographs were selected from patients treated between 1 Mar 2022 and 31 May 2022, while the second cycle's radiographs were selected from patients treated between 1 Sep 2022 and 30 Nov 2022. A staff member blinded to the audit process randomly selected radiographs from the radiology imaging software. However, only 28 BWs could be extracted during the defined audit period due to limited availability.

Following the first audit cycle, dental assistants and students were informed about the results. Staff training occurred while students underwent practical assessment. Videos of radiographic techniques were uploaded to the Virtual Learning Environment (VLE), an online teaching and learning platform, for students to review as needed.

Subsequently, the radiographs were assessed for quality using the Faculty of General Dental Practice (FGDP, UK) guidance notes (Gribben, 2021), as detailed in table 1.

The decision to repeat a radiograph may depend on the clinical indication for which it was taken and/or the patient's concern about excess radiation exposure due to a repeat radiograph.

Figures displaying a stacked bar chart and a line chart were created using the Python programming language (python 3.11) with the help of the Matplotlib library, allowing for the visualization and analysis of the radiographic quality data obtained from the audit cycles. These figures can be found in the Results section of the manuscript.

Table 1. Quality Rating Criteria for Radiographs Based on FGDP (UK) Guidance Notes

Quality Rating	*Basis*	*Target (Digital Imaging)*	*Target (Film Imaging)*
Diagnostically 'acceptable' ('A')	No errors or minimal errors in patient preparation, exposure, positioning, image processing, or image reconstruction; sufficient image quality to answer the clinical question	Not less than 95%	Not less than 90%
Diagnostically 'not acceptable' ('N')	Errors in patient preparation, exposure, positioning, image processing, or image reconstruction that render the image diagnostically unacceptable	Not greater than 5%	Not greater than 10%

Source: Gribben, M. (2021)

Results

Audits were conducted for intraoral radiographs, which included 50 BW and 50 PA in each cycle for both students and dental assistants, except for BWs taken by dental assistants, where only 28 could be extracted from the radiology imaging software during the defined time period for the audit.

Intraoral Bitewing Radiographs - Dental Assistants

Cycle 1: Out of the 14 BW radiographs taken by dental assistants, 2 (14%) were rated as 'acceptable' and 12 (86%) as 'not acceptable'. Cycle 2: Out of the 14 BW radiographs taken by dental assistants, 7 (50%) were rated as 'acceptable' and 7 (50%) as 'not acceptable'.

Intraoral Periapical Radiographs - Dental Assistants

Cycle 1: Out of the 50 PA radiographs taken by dental assistants, 35 (70%) were rated as 'acceptable' and 15 (30%) as 'not acceptable'. Cycle 2: Out of the 50 PA radiographs taken by dental assistants, 39 (78%) were rated as 'acceptable' and 11 (22%) as 'not acceptable'.

Intraoral Bitewing Radiographs - Students

Cycle 1: Out of the 50 BW radiographs taken by students, 13 (26%) were rated as 'acceptable' and 37 (74%) as 'not acceptable'). Cycle 2: Out of the 50 BW radiographs taken by students, 18 (36%) were rated as 'acceptable' and 32 (64%) as 'not acceptable'.

Intraoral Periapical Radiographs - Students

Cycle 1: Out of the 50 PA radiographs taken by students, 19 (38%) were rated as ‘acceptable’ and 31 (62%) as ‘not acceptable’.

Cycle 2: Out of the 50 PA radiographs taken by students, 36 (72%) were rated as ‘acceptable’ and 14 (28%) as ‘not acceptable’.

Figure 1 presents a comparison of the percentage of acceptable digital intraoral radiographs taken by students and dental assistants across two audit cycles using a stacked bar chart. The stacked bar chart clearly illustrates the distribution of acceptable and not acceptable radiographs for each group. Figure 2 provides a line plot visualization of the same data, showing the trend of improvement in radiograph quality between the two audit cycles for both students and dental assistants. The line plot highlights the change in percentages of acceptable radiographs over time, emphasizing the progress made. Refer to both Figure 1 and Figure 2 for a comprehensive understanding of the results and the different aspects of data representation.

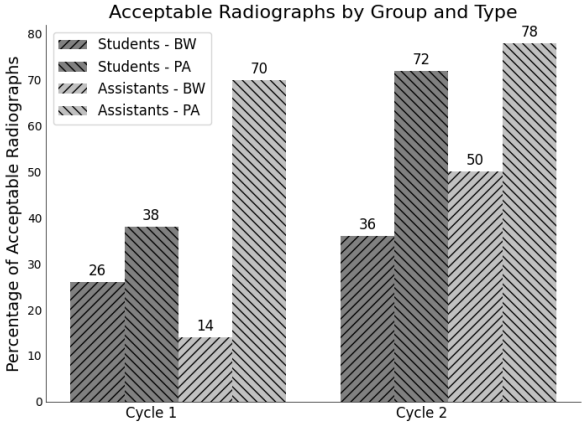

Figure 1. Comparison of the percentage of acceptable digital intraoral radiographs taken by students and dental assistants in two audit cycles. BW represents bitewing radiographs, and PA represents periapical radiographs. Gray bars with diagonal lines represent BW radiographs, and gray bars with reverse diagonal lines represent PA radiographs. Light gray bars indicate dental assistants, and dark gray bars indicate students.

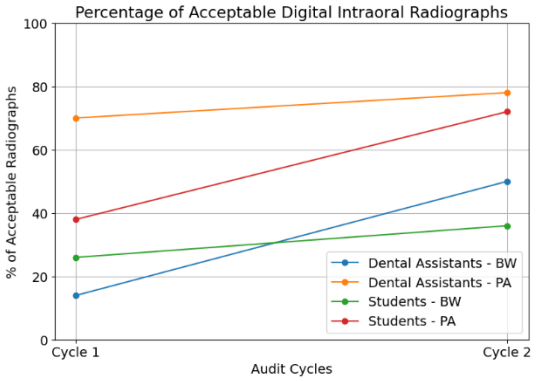

Figure 2. Line chart depicting the percentage of acceptable digital intraoral radiographs taken by dental assistants and students for bitewing (BW) and periapical (PA) radiographs across two audit cycles (Cycle 1 and Cycle 2). The chart demonstrates the improvement in the quality of radiographs between the two cycles for both groups.

Discussion

The overall results of the clinical audit suggested that the quality of radiographs taken by both undergraduate dental students and dental assistants were not meeting the desired standards. According to the FGDP (UK) Guidance Notes, the desired standard for digital imaging is that at least 95% of radiographs should be diagnostically acceptable, with no more than 5% being diagnostically unacceptable (Gribben, 2021). Similar observations have been reported in numerous other studies (Emanuel, 2003; Javed et al., 2020; Khan et al., 2020; Malhi, 2021; Patankar et al., 2019; Salami et al., 2017). The digital radiograph audit identified the most common errors as positioning issues, while cone-cut errors were eliminated due to the use of receptor holders. The radiographs in our study did not meet the desired standard primarily due to frequent positioning errors, which significantly affected the overall quality and diagnostic utility of the images.

Intraoral Bitewing Radiograph - Dental assistants

There was a noticeable increase in the number of ‘acceptable’ radiographs from Cycle 1 to Cycle 2 (14% to 50%) and a corresponding decrease in ‘not acceptable’ radiographs (86% to 50%). This improvement aligns with findings that raising

awareness of quality criteria for bitewing radiographs led to better outcomes (Emanuel, 2003). Sharing audit results with dental assistants and staff contributed to this increased awareness.

Limited availability of bitewing radiographs taken by dental assistants during the audit period might have skewed the percentages of 'not acceptable' radiographs. The higher frequency of complete new patient exams conducted by students, who often need baseline bitewings, could account for the lower number of bitewings taken by dental assistants. In private practice, dental assistants typically assist doctors in performing limited focus exams, which require more periapical radiographs due to their emphasis on addressing patients' chief complaints.

The initial high percentage of 'not acceptable' radiographs might be attributed to the pandemic-related lockdowns and subsequent restrictions on aerosol-generating procedures (AGPs), which limited opportunities for practice. The decline in 'not acceptable' radiographs may be due to dental assistants becoming more proficient and calibrated through consistent practice, adapting to new protocols, and gaining a better understanding of the radiographic techniques. Additionally, the availability of demonstration videos and training sessions provided dental assistants with essential guidance and visual aids, reinforcing best practices and enhancing their skills in acquiring high-quality radiographs.

Intraoral Periapical Radiograph - Dental assistants

From Cycle 1 to Cycle 2, the number of 'acceptable' radiographs increased from 70% to 78%, while 'not acceptable' radiographs decreased from 30% to 22%. The pandemic's impact on routine clinical dentistry and the resulting focus on emergency care could explain the initially high percentage of 'not acceptable' radiographs. The decline may be due to sharing audit results, which created an awareness of the areas that needed improvement, calibrating dental assistants by providing feedback on their performance, and offering demonstration videos and training sessions that addressed common mistakes and emphasized the importance of adhering to established guidelines and protocols. This comprehensive approach helped enhance the dental assistants' skills, ultimately leading to better-quality radiographs.

Bitewing radiographs had a higher overall percentage of 'not acceptable' outcomes due to positioning errors and insufficient knowledge about the indications for bitewing radiographs. The higher overall percentage of 'acceptable' periapical radiographs might also be influenced by changes in standards for rating radiograph quality. Criteria for whether a radiograph needs to be retaken may depend on the specific task it was taken for, or even the patient's concerns about additional radiation exposure. These criteria and the ALARA (As Low As Reasonably Achievable) principle consider radiographs with faults that do not affect diagnostic quality as acceptable (Berkhout, 2015), which may contribute to the increased number of acceptable radiographs.

Intraoral Bitewing Radiograph - Students

Between Cycle 1 and Cycle 2, the number of 'acceptable' radiographs increased from 26% to 36%, while 'not acceptable' radiographs decreased from 74% to 64%. The initial high percentage of 'not acceptable' radiographs could be due to the pandemic's disruption of routine clinical dentistry, leading to fewer opportunities for students to practice and refine their skills, and limited access to regular supervision and feedback from instructors. The reduction might be attributed to the practice sessions for students after the first cycle, where they received hands-on guidance, the availability of demonstration videos that offered visual aid for proper radiograph techniques, and raising awareness of the audit results, which created a sense of responsibility and motivation for improvement.

Intraoral Periapical Radiograph - Students

From Cycle 1 to Cycle 2, the number of 'acceptable' radiographs increased from 38% to 72%, and the number of 'not acceptable' radiographs decreased from 62% to 28%. The reasons for the initially high percentage of 'not acceptable' radiographs could be attributed to the pandemic's impact on routine clinical dentistry, as previously mentioned. The reduction in 'not acceptable' radiographs might be due to practice sessions that provided a platform for students to correct their mistakes, the availability of demonstration videos that helped students visualize proper techniques, and

sharing audit results during didactic classes, which fostered a culture of continuous learning and progress among students.

The high percentage of 'not acceptable' bitewing radiographs among students might be due to positioning errors, lack of knowledge regarding bitewing radiograph indications, and insufficient understanding of ideal quality criteria. The change in standards for rating radiograph quality, which now combines Grade 1 & Grade 2 quality from the previous classification under the 'acceptable' category in the recent 2020 classification, might contribute to the increased number of acceptable radiographs. Criteria for whether a radiograph needs to be repeated may depend on the reason it was taken or even the patient's concern regarding additional radiation exposure.

Interestingly, students were able to produce a higher percentage of 'acceptable' bitewing radiographs than dental assistants during the first audit cycle. This discrepancy might be due to the smaller number of bitewing radiographs taken by dental assistants.

The overall lower quality of bitewing and periapical radiographs in this study might be attributed to their digital nature. Some studies have found digital radiographs to be of inferior quality compared to conventional radiographs. However, quality standards for digital radiographs are higher than those for conventional radiographs (Berkhout et al., 2003). The ease of repeating digital radiographs might lead to less attention to positioning. It is crucial to ensure dental staff are aware of indications and revise ideal quality criteria for radiographs regularly.

There is a lack of studies comparing radiographs taken by dental assistants to those taken by students. While some studies have conducted audits in student, undergraduate, and postgraduate pediatric dentistry settings, they have consistently found that results fall below desired standards (Javed et al., 2020; Patankar et al., 2019; Salami et al., 2017). One study reported significant improvement after the second audit cycle but was conducted among graduated dentists in the UK without remedial actions (Emanuel et al., 2005). Mere awareness of audit results led to increased care and caution, overcoming quality issues. Thus, training dental students about quality assurance, as part of the undergraduate curriculum, could help them achieve set standards through internal feedback (Field et al., 2017).

In our study, we evaluated the quality of indirect digital intraoral radiographs taken by dental students and dental assistants within an undergraduate dental clinic setting. While our audit results offer valuable insights, it is crucial to consider the representativeness of our sample. Our findings may not wholly reflect the radiograph quality taken by dental professionals in other clinical environments and may not be generalizable to all dental professionals. Nevertheless, our results underscore the importance of ongoing training, feedback, and quality assurance measures in enhancing radiograph quality.

The high frequency of positioning errors in our study emphasizes the need for proper training and equipment usage. The age and type of radiographic equipment used in the clinic could have potentially contributed to these errors. Upgrading to newer equipment, which often includes advanced positioning aids, might help reduce error rates. Furthermore, it is vital to stress the role of dental education and training in ensuring dental professionals use radiographic equipment correctly and minimize errors. By addressing these points, we can provide a more comprehensive analysis of factors influencing dental radiograph quality and strategies to improve it.

In our study, we observed that dental assistants produced a higher percentage of acceptable periapical radiographs than dental students, while dental students had a higher percentage of acceptable bitewing radiographs. This observation suggests that specific training and practice areas may affect radiograph quality. Therefore, it is essential to assess dental curricula and training modules to ensure all dental professionals receive comprehensive and consistent training in acquiring high-quality radiographs. By doing so, we can help reduce performance variations among dental practitioners and enhance overall radiograph quality in clinical settings.

From a dental educator's perspective, this study highlights the significance of constantly refining dental education curricula and tailoring the

learning experience to target specific areas that need improvement. Instructors should continuously evaluate students' and dental assistants' progress, addressing any weaknesses in their radiographic techniques. By providing individualized feedback and supplemental educational resources, dental educators can empower students and dental assistants to develop the necessary skills and confidence to take high-quality radiographs consistently.

The COVID-19 pandemic has undeniably reshaped the landscape of dental care, necessitating significant adjustments to both clinical practices and educational methods. The need for innovative and adaptive approaches to maintain the quality of dental radiography emerged as dental professionals grappled with the challenges posed by the pandemic, such as restrictions on aerosol-generating procedures and the shift towards emergency care. Remote learning tools, including demonstration videos and virtual training sessions, have bridged the gap between theoretical knowledge and practical application, despite the limitations imposed by the pandemic. Sharing audit results and fostering open discussions during didactic classes provided an opportunity for reflection and growth, demonstrating the resilience of the dental community.

Incorporating these innovative alternatives into regular dental education and practice can lead to even greater improvements in radiographic quality. By integrating supplementary educational tools and resources alongside traditional methods, dental professionals can benefit from a more comprehensive and accessible learning experience, further enhancing the quality of dental radiography. The pandemic has served as a catalyst for positive change, prompting the dental community to embrace new approaches and technologies that will undoubtedly contribute to the ongoing evolution of dental care and education.

It is important to acknowledge that our study took place in an undergraduate dental clinic, where dental students and dental assistants operate under the supervision of experienced professionals. In real-world clinical settings, dental practitioners may lack the same level of oversight and support. Therefore, promoting a culture of continuous learning, self-assessment, and peer feedback is essential for dental professionals to maintain and enhance their radiographic skills. By cultivating a supportive environment that encourages collaboration and learning, we can further improve the overall quality of dental radiographs and elevate patient care.

Future research should focus on a more diverse range of clinical settings to further explore the factors influencing radiograph quality and generalizability of our findings. Moreover, examining the effectiveness of various educational interventions and quality improvement measures can provide valuable guidance for dental professionals seeking to enhance their radiographic skills and, ultimately, improve patient outcomes.

Conclusions and Recommendations

This study provided valuable insights into the quality of indirect digital intraoral radiographs taken by undergraduate dental students and dental assistants. While there were initial challenges with meeting the desired standards set by the FGDP (UK) Guidance Notes, significant improvements were observed following feedback and additional training. Specifically, dental assistants showed a higher percentage of acceptable periapical radiographs, while dental students showed improvement in bitewing radiographs. These findings underscore the importance of continuous training, feedback, and quality assurance measures. Addressing specific training and practice areas is essential to ensure consistent radiographic skills among dental professionals. The study highlights the need for upgrading radiographic equipment and incorporating advanced positioning aids to further enhance radiograph quality.

Upgrading radiographic equipment and incorporating advanced positioning aids can help reduce errors and improve radiograph quality. Dental education and training play a crucial role in ensuring proper usage of radiographic equipment and minimizing errors. By refining dental curricula and providing individualized feedback, dental educators can help students and dental assistants develop the necessary skills and confidence to consistently take high-quality radiographs.

Although our study was limited to a specific clinic setting, the lessons learned can be applied to other clinical environments. It is essential to foster a

culture of continuous learning, self-assessment, and peer feedback to help dental professionals maintain and enhance their radiographic skills. By promoting a supportive environment that encourages collaboration and learning, we can further improve the overall quality of dental radiographs and elevate patient care.

Conflict of interests

The authors report no conflicts of interest.

Ethical approval

The study was approved by the Ethics Committee of Oman Dental College (ODC-2023-TN-181).

Data availability statement

The data used in this study is available upon request from the corresponding author.

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