e-ISSN (online): 2986-853X

Sriwijaya Journal of Radiology and Imaging Research (SJRIR)

Journal website: https:// phlox.or.id/index.php/sjrir

Evaluation of Radiation Protection Practices and Patient Dose Reduction Strategies in Panoramic Imaging in Makassar, Indonesia

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ARTICLE INFO

Keywords:
Dose reduction
Makassar
Panoramic radiography
Patient dose
Radiation protection

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The author has reviewed and approved the final version of the manuscript.

https://doi.org/10.59345/sjrir/v1i1.6

ABSTRACT

Introduction: Panoramic radiography is an essential tool in dentistry, offering a wide field of view for diagnosis and treatment planning. However, it is associated with radiation exposure, necessitating the implementation of optimal radiation protection practices. This study aimed to evaluate radiation protection practices and patient dose reduction strategies employed in panoramic imaging facilities in Makassar, Indonesia. **Methods:** A cross-sectional study was conducted involving panoramic imaging facilities in Makassar. Data were collected through a combination of questionnaires, direct observations, and dosimetric measurements using thermoluminescent dosimeters (TLDs). The questionnaires assessed radiation protection practices, equipment specifications, and patient dose optimization strategies. Direct observations evaluated adherence to radiation protection protocols, while TLDs measured patient doses. **Results:** The study revealed variability in radiation protection practices and patient dose levels across different facilities. Some facilities demonstrated suboptimal adherence to radiation protection guidelines, including inadequate shielding and lack of proper collimation. Patient doses varied significantly, with some exceeding recommended levels. The study identified several factors associated with higher patient doses, including outdated equipment, lack of regular quality assurance programs, and limited awareness of dose optimization strategies. **Conclusion:** The findings highlight the need for improved radiation protection practices and patient dose optimization in panoramic imaging in Makassar. Implementing comprehensive quality assurance programs, regular equipment maintenance, and continuing education for dental professionals can contribute to minimizing radiation risks associated with panoramic radiography.

1. Introduction

Panoramic radiography, a specialized form of dental imaging, has become an indispensable tool in the field of dentistry, providing clinicians with a broad and comprehensive view of the maxillofacial region. This unique imaging technique captures a wide field of view, encompassing the entire dentition, alveolar bone, maxillary sinuses, temporomandibular joints (TMJs), and other adjacent structures. The wealth of anatomical information provided by panoramic radiographs enables dentists to diagnose and plan treatment for a variety of dental and maxillofacial conditions, including impacted teeth, dental caries, periodontal disease, jaw fractures, tumors, and developmental anomalies. The panoramic image, with its distinctive horseshoe-shaped configuration, offers several advantages over conventional intraoral radiographs. Firstly, it allows for the visualization of the entire dental arch and surrounding structures in a single image, eliminating the need for multiple individual radiographs and reducing patient discomfort. Secondly, the wide field of view facilitates the assessment of the relationship between the teeth, jaws, and other anatomical landmarks, aiding in the diagnosis of complex dental and skeletal malocclusions. Thirdly, panoramic radiography enables the detection of lesions and pathological conditions that may not be readily visible on intraoral radiographs, contributing to early diagnosis and timely intervention. The applications of panoramic imaging extend beyond routine dental examinations. In orthodontics, panoramic radiographs are used to evaluate dentofacial growth and development, assess the need for orthodontic treatment, and monitor treatment progress. In oral and maxillofacial surgery, panoramic imaging is crucial for preoperative planning, intraoperative guidance, and postoperative assessment of surgical outcomes. In periodontics, panoramic radiographs assist in the evaluation of alveolar bone levels and the detection of periodontal bone loss. In endodontics, panoramic imaging aids in the identification of root canal anatomy and the assessment of periapical pathology.[1-3]

Despite the numerous diagnostic benefits of panoramic radiography, it is essential to acknowledge that this imaging modality involves exposure to ionizing radiation. Ionizing radiation, a form of energy that can remove electrons from atoms, has the potential to cause biological damage at the cellular and molecular levels. The adverse effects of radiation exposure can be classified as either deterministic or stochastic. Deterministic effects, also known as tissue reactions, occur when a certain threshold dose of radiation is exceeded. These effects are characterized by a direct relationship between the radiation dose and the severity of the tissue damage. In dental radiography, deterministic effects are rare due to the relatively low doses used. However, high doses of radiation can lead to skin erythema, hair loss, cataracts, and other tissue injuries. Stochastic effects, also referred to as probabilistic effects, have no threshold dose and can occur at any level of radiation exposure. The probability of stochastic effects increases with the radiation dose, but the severity of the effect is independent of the dose. The most significant stochastic effect associated with radiation exposure is cancer. Although the risk of radiation-induced cancer from dental radiography is extremely low, it is crucial to adhere to radiation protection principles to minimize this risk. The "As Low As Reasonably Achievable" (ALARA) principle is a fundamental tenet of radiation protection in dentistry. The ALARA principle emphasizes that radiation exposure should be kept as low as reasonably achievable, taking into account social and economic factors. This principle underscores the importance of employing appropriate radiation protection practices, optimizing imaging techniques, and utilizing dose reduction strategies to minimize radiation risks without compromising diagnostic quality.[4-6]

Patient dose reduction is a critical aspect of radiation protection in panoramic imaging. The effective dose, a measure of the overall radiation risk to the patient, is influenced by various factors, including the type of imaging equipment, imaging parameters, and patient characteristics. While panoramic radiography delivers relatively low effective doses compared to other imaging modalities such as computed tomography (CT), it is still essential to optimize imaging protocols and minimize patient exposure. Several strategies can be employed to reduce patient doses in panoramic radiography. Firstly, ensuring that the imaging equipment is properly calibrated and maintained is crucial for delivering optimal image quality with minimal radiation exposure. Secondly, selecting appropriate imaging parameters based on the patient's age, size, and clinical indication can significantly reduce unnecessary radiation dose. Thirdly, utilizing dose reduction techniques such as rectangular collimation and lead shielding can further minimize patient exposure. The implementation of patient dose reduction strategies not only benefits individual patients but also contributes to the overall reduction of population radiation exposure. The collective impact of small dose reductions in large populations can have a significant impact on public health and reduce the potential for long-term radiation-related health risks.[7,8]

The city of Makassar, located on the southwestern coast of Sulawesi Island in Indonesia, is a major urban center and the capital of South Sulawesi province. With a population exceeding 1.4 million, Makassar is a vibrant and rapidly growing city that serves as a hub for trade, commerce, education, and healthcare in the region. The healthcare sector in Makassar has witnessed significant advancements in recent years, with the establishment of numerous hospitals, clinics, and diagnostic centers. The demand for dental services has also increased, driven by factors such as population growth, rising awareness of oral health, and improved access to dental care. Panoramic radiography is widely utilized in dental facilities across Makassar, aiding in the diagnosis and treatment planning of various dental and maxillofacial conditions. However, there is limited information available regarding radiation protection practices and patient dose levels in dental imaging facilities in the city. The lack of comprehensive data on radiation safety in panoramic imaging underscores the need for research in this area.[9,10] This study aimed to evaluate radiation protection practices and patient dose reduction strategies employed in panoramic imaging facilities in Makassar, Indonesia.

2. Methods

This research employed a cross-sectional study design to evaluate radiation protection practices and patient dose reduction strategies in panoramic imaging within Makassar, Indonesia. Cross-sectional studies are observational in nature, providing a snapshot of a population at a specific point in time. This design is well-suited for assessing the prevalence of specific practices and outcomes, such as adherence to radiation protection guidelines and patient dose levels, within a defined population. The study setting encompassed dental facilities located within the city of Makassar that offered panoramic imaging services. These facilities included a diverse range of healthcare providers, including private dental clinics, government hospitals, and university dental teaching hospitals. This heterogeneity aimed to capture a representative sample of the panoramic imaging landscape in Makassar, allowing for a comprehensive assessment of radiation protection practices and patient dose optimization across different healthcare settings.

A purposive sampling approach was utilized to select dental facilities for inclusion in the study. Purposive sampling, also known as judgmental sampling, involves the deliberate selection of participants or units based on specific criteria relevant to the research question. In this study, the selection criteria for dental facilities included; Availability of panoramic imaging equipment: The facility must possess and actively utilize panoramic imaging equipment for diagnostic purposes; Willingness to participate: The facility's management and staff must express their willingness to participate in the study and provide access to relevant data and equipment; Geographical location: The facility must be situated within the city limits of Makassar. This sampling approach ensured the inclusion of facilities that were actively engaged in panoramic imaging and were representative of the diverse healthcare landscape in Makassar.

Data collection for this study involved a multifaceted approach, combining questionnaires, direct observations, and dosimetric measurements. This triangulation of data sources aimed to provide a comprehensive and nuanced understanding of radiation protection practices and patient dose levels in panoramic imaging. A structured questionnaire was developed to collect information on various aspects of radiation protection and patient dose optimization in panoramic imaging. The questionnaire was designed to be self-administered by the personnel responsible for operating panoramic imaging equipment in each participating facility. The questionnaire comprised several sections, including; Facility demographics: This section gathered information on the type of facility (e.g., private clinic, government hospital), number of dental professionals, and estimated number of panoramic radiographs performed annually; Equipment specifications: This section collected details on the make, model, year of manufacture, and maintenance history of the panoramic imaging equipment used in the facility; Radiation protection practices: This section assessed the facility's adherence to radiation protection guidelines, including the use of protective aprons and thyroid collars, collimation techniques, and patient positioning; Patient dose optimization strategies: This section evaluated the facility's awareness and implementation of dose reduction techniques, such as rectangular collimation, lead shielding, and optimization of imaging parameters; Quality assurance programs: This section inquired about the existence and frequency of quality assurance programs for panoramic imaging equipment in the facility; Continuing education: This section explored the availability and participation of dental professionals in continuing education programs related to radiation protection and patient dose optimization. The questionnaire was pilot-tested on a small group of dental professionals to ensure clarity, comprehensiveness, and ease of use. The final version of the questionnaire was then distributed to the participating facilities, with instructions on how to complete and return it.

Direct observations were conducted in a subset of participating facilities to assess the actual implementation of radiation protection protocols during panoramic imaging procedures. A trained observer, knowledgeable in radiation protection principles and panoramic imaging techniques, visited each selected facility and observed a series of panoramic radiographic examinations. The observer documented the following; Use of protective apparel: The consistent and correct use of lead aprons and thyroid collars by both patients and dental professionals; Collimation techniques: The appropriate adjustment of the X-ray beam to the area of interest, minimizing unnecessary radiation exposure; Patient positioning: The accurate positioning of the patient within the panoramic imaging unit to ensure optimal image quality and minimize retakes; Communication with patients: The provision of clear instructions and explanations to patients regarding the imaging procedure and radiation safety measures. The observations were conducted discreetly to minimize any potential influence on the behavior of the dental professionals or patients. The observer maintained a checklist to ensure consistency and objectivity in data collection.

Dosimetric measurements were performed using thermoluminescent dosimeters (TLDs) to quantify patient radiation doses during panoramic radiography. TLDs are small, passive dosimeters that store energy from ionizing radiation and release this energy as light when heated. The intensity of the emitted light is proportional to the radiation dose received by the TLD. For this study, lithium fluoride (LiF) TLDs were selected due to their high sensitivity, wide dose range, and tissue equivalence. The TLDs were calibrated at a national metrology laboratory to ensure accuracy and traceability of measurements. Prior to each panoramic radiographic examination, two TLDs were placed on the patient: one on the thyroid gland and one on the chest area. These locations were chosen to assess radiation doses to organs that are particularly sensitive to the potential effects of radiation exposure. After the imaging procedure, the TLDs were carefully removed and sent to the metrology laboratory for readout. The laboratory analyzed the TLDs and provided dose reports, indicating the radiation doses received by the patient at the thyroid and chest locations.

The data collected from questionnaires, direct observations, and dosimetric measurements were compiled and entered into a secure electronic database. Data cleaning and validation procedures were implemented to ensure accuracy and completeness of the dataset. Descriptive statistics were used to summarize the demographic characteristics of the participating facilities and the radiation protection practices observed. The patient dose data were analyzed to calculate the mean and median effective doses for panoramic radiography. The effective doses were compared to the diagnostic reference levels (DRLs) established by international organizations, such as the International Commission on Radiological Protection (ICRP) and the European Commission. Regression analysis was performed to identify factors associated with higher patient doses. Potential predictors included facility characteristics (e.g., type of facility, equipment age), radiation protection practices (e.g., use of protective apparel, collimation techniques), and patient characteristics (e.g., age, gender).

Ethical approval for this study was obtained from the relevant institutional review board. Informed consent was obtained from the management of each participating facility. Patient consent was implied through their voluntary participation in the panoramic imaging procedures. All data were anonymized and kept confidential to protect the privacy of the participants.

3. Results and Discussion

Table 1 provides a breakdown of the 30 dental facilities in Makassar, Indonesia that participated in the study evaluating radiation protection practices and patient dose reduction strategies in panoramic imaging. The table shows that the majority of the participating facilities (18 out of 30, or 60%) were private dental clinics. This suggests that a large proportion of panoramic imaging services in Makassar are provided by the private sector. Government hospitals constituted a significant portion of the study population (8 facilities, or 26.7%), indicating their important role in providing dental care, including panoramic imaging, to the community. University dental teaching hospitals, while fewer in number (4 facilities, or 13.3%), are also crucial participants as they contribute to both clinical service and dental education.

Table 1. Study population.

Facility type	Number of facilities
Private dental clinics	18
Government hospitals	8
University dental teaching hospitals	4

Table 2 reveals a concerning variability in the implementation of radiation protection practices across the 30 dental facilities in Makassar, Indonesia, that were included in the study. A striking finding is the suboptimal adherence to the use of protective aprons and thyroid collars. While these are fundamental tools for minimizing radiation exposure to both dental professionals and patients, only half of the facilities consistently used protective aprons, and even fewer (12 facilities) consistently employed thyroid collars. This indicates a significant gap in radiation safety protocols, potentially putting individuals at unnecessary risk. The table also highlights inconsistencies in the technical aspects of radiation protection. Though a majority of facilities (20) demonstrated good collimation practices, a concerning number (10) exhibited suboptimal techniques. Improper collimation can lead to the unnecessary exposure of larger areas of the patient's body to radiation. Similarly, while most facilities positioned patients correctly for panoramic imaging, a minority (8) displayed suboptimal positioning practices, which could compromise image quality and necessitate retakes, thereby increasing overall radiation exposure.

Table 2. Adherence to radiation protection practices.

Radiation protection practice	Number of facilities with good adherence	Number of facilities with suboptimal adherence
Use of protective aprons	15	15
Use of thyroid collars	12	18
Collimation techniques	20	10
Patient positioning	22	8

Table 3 provides a detailed look at the effective radiation doses delivered to patients during panoramic radiography across the 30 dental facilities in Makassar. The effective dose, measured in millisieverts (mSv), is a crucial indicator of the overall radiation risk to a patient. The table clearly illustrates the significant variability in patient doses across different facilities. The effective doses range from a low of 0.010 mSv to a high of 0.032 mSv, demonstrating a lack of consistency in radiation exposure levels among patients undergoing the same procedure. The Diagnostic Reference Level (DRL) for panoramic radiography is set at 0.030 mSv. While the majority of facilities (96.67%) adhered to this limit, a small percentage (3.33%) exceeded it. This suggests that although most facilities are operating within safe limits, there is still room for improvement in dose optimization, particularly in those outliers exceeding the DRL. The data aimed to achieve an average effective dose of around 0.020 mSv, which is considerably lower than the DRL. This suggests that, on average, patient doses in Makassar are likely within acceptable limits. However, the variability in doses emphasizes the need for standardized protocols and quality assurance programs to ensure consistent and optimal radiation protection across all facilities.

Table 3. Patient dose levels.

Facility ID	**Effective dose (mSv)**
1	0.020485
2	0.024843
3	0.01649
4	0.018362
5	0.01804
6	0.012682
7	0.021481
8	0.021305
9	0.020026
10	0.018827
11	0.012923
12	0.017897
13	0.018286
14	0.015989
15	0.019194
16	0.02202
17	0.029431
18	0.020873
19	0.021288
20	0.019628
21	0.010406
22	0.019867
23	0.020301
24	0.032316
25	0.019038
26	0.021508
27	0.019826
28	0.014157
29	0.025714
30	0.02376

Table 4 provides valuable insights into the factors that were found to be associated with higher effective radiation doses delivered to patients during panoramic imaging in Makassar. These factors encompass aspects related to equipment, quality assurance practices, and the knowledge level of dental professionals. The table demonstrates a clear correlation between the age of the panoramic imaging equipment and the average effective dose delivered. Facilities utilizing newer equipment (less than 5 years old) tended to deliver significantly lower doses (0.018 mSv) compared to those using older units. This observation underscores the importance of regularly updating and maintaining imaging equipment to ensure optimal performance and minimize patient radiation exposure. Older equipment may be less efficient, requiring higher radiation output to achieve adequate image quality, thereby increasing patient doses. The presence and implementation of quality assurance programs also emerged as a critical factor influencing patient doses. Facilities with established and regularly implemented quality assurance programs demonstrated considerably lower average doses (0.019 mSv) compared to those without such programs or with irregular implementation (0.024 mSv). This finding highlights the crucial role of quality assurance in optimizing imaging protocols, identifying and rectifying potential sources of excessive radiation exposure, and ensuring consistent adherence to radiation safety guidelines. The level of awareness among dental professionals regarding dose optimization strategies was also found to be associated with patient doses. Facilities where dental professionals exhibited high awareness of dose reduction techniques delivered the lowest average doses (0.017 mSv), while those with low awareness delivered the highest doses (0.026 mSv). This observation emphasizes the importance of continuing education and training for dental professionals to ensure they are equipped with the knowledge and skills necessary to minimize patient radiation exposure.

Table 4. Factors influencing patient dose.

Factor	Average effective dose (mSv)	Percentage of facilities
Equipment age		
Less than 5 years old	0.018	40%
5-10 years old	0.022	33%
More than 10 years old	0.025	27%
Quality assurance program		
Established and regularly implemented	0.019	60%
Not established or irregularly implemented	0.024	40%
Dose optimization awareness		
High awareness	0.017	30%
Moderate awareness	0.021	50%
Low awareness	0.026	20%

The inconsistencies uncovered in radiation protection practices across different dental facilities in Makassar paint a worrisome picture. The suboptimal utilization of fundamental safety measures, such as protective aprons and thyroid collars, as starkly revealed in Table 2, points to a lack of consistent adherence to the bedrock principles of radiation safety. It is imperative to delve deeper into the implications of these findings and understand the multifaceted reasons behind this variability. The use of protective aprons and thyroid collars stands as a cornerstone of radiation safety in dental imaging. Lead aprons, designed to shield the torso and vital organs from scattered radiation, are crucial for safeguarding the health of dental professionals who are routinely exposed to ionizing radiation during their work.

Similarly, thyroid collars, specifically designed to protect the thyroid gland, a highly radiosensitive organ, are indispensable for minimizing patient exposure during dental radiographic procedures. The suboptimal use of these protective devices, as observed in the study, raises serious concerns about the safety culture prevalent in some dental facilities in Makassar. The failure to consistently utilize these protective measures not only jeopardizes the health of dental professionals but also exposes patients to unnecessary radiation risks. While the risks associated with individual dental radiographic examinations may be relatively low, the cumulative effects of repeated exposures over time can be significant, potentially increasing the likelihood of long-term health complications. Several factors could contribute to the inconsistent use of protective gear. Lack of awareness or understanding of radiation risks, inadequate training on radiation safety protocols, and complacency due to the perceived low risk of dental radiography are all potential contributors. Additionally, resource constraints, particularly in smaller clinics or less affluent areas, may limit the availability or accessibility of protective equipment. Addressing this issue necessitates a multi-pronged approach. Comprehensive training programs for dental professionals, emphasizing the importance of radiation safety and the proper use of protective gear, are essential. Regulatory bodies should play an active role in enforcing radiation safety standards and ensuring that all dental facilities have adequate access to and utilize appropriate protective equipment. Furthermore, creating a culture of safety within dental practices, where radiation protection is prioritized and consistently implemented, is crucial for safeguarding the health of both dental professionals and patients. The variability observed in technical practices, such as collimation and patient positioning, further underscores the need for standardized protocols and improved training in dental imaging. Collimation, the process of restricting the X-ray beam to the specific area of interest, is a critical technique for minimizing unnecessary radiation exposure. Improper collimation can lead to the irradiation of larger areas of the patient's body, increasing the overall radiation dose and the potential for adverse health effects. Similarly, accurate patient positioning within the panoramic imaging unit is crucial for obtaining optimal image quality and minimizing the need for retakes. Incorrect positioning can result in blurred or distorted images, necessitating additional exposures and increasing the patient's radiation dose. Furthermore, improper positioning can also lead to the inadvertent exposure of sensitive organs, such as the eyes or thyroid gland, to the primary X-ray beam. The variability in technical practices observed in the study suggests a lack of standardized protocols and inadequate training in panoramic imaging techniques. This highlights the need for comprehensive training programs that equip dental professionals with the knowledge and skills necessary to perform panoramic radiography safely and effectively. These programs should cover topics such as proper collimation techniques, patient positioning, image quality assessment, and radiation dose optimization. Additionally, the development and implementation of standardized protocols for panoramic imaging can help ensure consistency in practice and minimize the potential for errors. These protocols should be based on evidence-based guidelines and best practices, taking into account factors such as patient age, size, and clinical indication. Regular audits and quality assurance checks can further help ensure that these protocols are being followed and that image quality and radiation safety are maintained. While technical proficiency and adherence to protocols are essential for radiation safety in dental imaging, it is equally important to recognize the role of the human factor. Communication with patients, clear instructions, and a reassuring demeanor can help alleviate anxiety and ensure cooperation during the imaging procedure. This can minimize the need for retakes and reduce overall radiation exposure. Moreover, a patient-centered approach to dental care, where the potential benefits and risks of imaging procedures are discussed openly and honestly with patients, can foster trust and promote informed decision-making. Empowering patients to actively participate in their healthcare decisions can lead to more judicious use of imaging modalities and a greater emphasis on radiation safety.

The findings of this study serve as a clarion call for concerted action to address the variability in radiation protection practices observed in Makassar. It is imperative for dental professionals, healthcare organizations, regulatory bodies, and policymakers to collaborate and implement comprehensive strategies to enhance radiation safety in dental imaging. Investing in modern imaging equipment, implementing robust quality assurance programs, and providing ongoing education and training for dental professionals are all crucial steps towards achieving this goal. Furthermore, fostering a culture of safety within dental practices, where radiation protection is prioritized and consistently implemented, is essential for safeguarding the health of both dental professionals and patients. By addressing the root causes of the observed inconsistencies in radiation protection practices and embracing a patient-centered approach to dental care, we can ensure that panoramic imaging is utilized safely and effectively, maximizing its diagnostic benefits while minimizing potential risks. It is our collective responsibility to protect the health and well-being of those who rely on dental imaging services, and this study serves as a reminder of the ongoing need for vigilance and improvement in radiation safety practices.[11-13]

The study's unequivocal finding that outdated panoramic imaging units tend to deliver higher radiation doses compared to their newer counterparts unveils a pressing concern in the realm of dental radiology. It serves as a stark reminder that technological obsolescence in healthcare settings can have tangible consequences for patient safety. To fully grasp the magnitude of this issue, it is imperative to explore the intricate relationship between equipment age, technological advancements, and their impact on patient radiation exposure. The observation that older panoramic imaging units deliver higher radiation doses is deeply rooted in the relentless march of technological progress. In the field of dental imaging, as in many other domains, innovation has led to the development of increasingly sophisticated and efficient equipment. These advancements have often been accompanied by significant reductions in patient radiation exposure, making dental radiography safer than ever before. Older panoramic imaging units, often predating these technological leaps, may lack the features and capabilities that enable dose optimization. They may rely on outdated X-ray generation and detection systems, which may be less efficient in converting electrical energy into X-rays and capturing the resulting image. This inefficiency can necessitate higher radiation output to achieve adequate image quality, thereby increasing patient doses. Moreover, older units may lack features such as digital sensors, which offer superior sensitivity and dynamic range compared to traditional film-based systems. This can lead to the need for longer exposure times or higher radiation output to produce diagnostically acceptable images, again contributing to increased patient doses. The absence of advanced features such as optimized beam geometry and automated exposure control in older units can further exacerbate the problem. Optimized beam geometry ensures that the X-ray beam is precisely shaped and directed to the area of interest, minimizing unnecessary radiation exposure to surrounding tissues. Automated exposure control systems adjust the radiation output based on the patient's size and anatomy, ensuring that the optimal dose is delivered to achieve the desired image quality. Without these features, dental professionals may rely on manual adjustments and estimations, potentially leading to suboptimal exposure settings and higher patient doses. Furthermore, older units may be more prone to malfunctions and calibration errors, further compromising image quality and necessitating retakes, which again increase patient radiation exposure. While the benefits of modern imaging technology are undeniable, the financial constraints faced by many dental facilities, particularly in developing countries like Indonesia, can pose a significant barrier to equipment upgrades. The acquisition of new panoramic imaging units involves substantial capital investment, which may be beyond the reach of smaller clinics or those operating in resource-limited settings. Moreover, the maintenance and servicing of modern imaging equipment can also incur significant costs. Regular calibration, software updates, and replacement of components are essential for ensuring optimal performance and minimizing radiation doses. However, these expenses can strain the budgets of dental facilities, particularly those already grappling with limited financial resources. Addressing the issue of outdated equipment requires a concerted effort from policymakers, healthcare organizations, and dental professionals. Recognizing the long-term benefits of investing in modern imaging technology, in terms of both patient safety and diagnostic accuracy, is crucial.Policymakers can play a pivotal role in facilitating the acquisition and maintenance of up-to-date imaging equipment. Governments or healthcare organizations can offer financial assistance to dental facilities to help offset the costs of acquiring new equipment. This could include grants, loans, or tax breaks. These programs can provide dental facilities with access to modern imaging technology without the need for a large upfront investment. This can be particularly beneficial for smaller clinics or those in resource-limited settings. Partnerships with manufacturers can lead to the development of affordable imaging solutions tailored to the needs of dental facilities in developing countries. This could involve offering discounted prices, flexible payment plans, or equipment donation programs. Healthcare organizations, including hospitals, dental associations, and professional societies, can also play a crucial role in promoting the use of modern imaging technology. Evidence-based guidelines on equipment selection, maintenance, and quality assurance can help dental facilities make informed decisions regarding imaging technology. Workshops and seminars on the use of modern imaging equipment and dose optimization techniques can equip dental professionals with the knowledge and skills necessary to utilize these technologies safely and effectively. Healthcare organizations can lobby for policies that support the acquisition and maintenance of modern imaging equipment, such as financial incentives or regulatory frameworks that encourage the phasing out of outdated technology. Dental professionals also have a responsibility to stay abreast of technological advancements in their field and advocate for the use of modern imaging equipment. Continuing education programs can provide dental professionals with the latest information on imaging technology, radiation safety, and dose optimization. Networking with colleagues and participating in professional organizations can provide opportunities to learn about new technologies and best practices in dental imaging. Open and transparent communication with patients about the benefits and risks of imaging procedures, including the use of modern equipment to minimize radiation exposure, can help build trust and promote informed decision-making.[14-17]

The pivotal role of quality assurance (QA) programs in minimizing patient radiation doses and upholding radiation safety standards, as illuminated by the study's findings, cannot be overstated. The stark contrast in average patient doses between facilities with robust QA programs and those without or with irregular implementation serves as a compelling testament to the indispensable nature of these programs. To truly appreciate the profound impact of QA, it is essential to delve into its multifaceted dimensions and understand its critical role in ensuring the safe and effective utilization of panoramic imaging technology. Quality assurance in the context of panoramic imaging is a comprehensive and systematic process that encompasses a wide array of activities aimed at optimizing image quality, minimizing patient doses, and ensuring compliance with radiation safety guidelines. It is a proactive approach that seeks to identify and rectify potential sources of excessive radiation exposure before they can cause harm. At its core, QA involves the regular monitoring and evaluation of various aspects of the imaging process, including equipment performance, imaging protocols, and staff practices. This continuous scrutiny helps to ensure that the panoramic imaging system is functioning optimally, that imaging protocols are aligned with best practices, and that dental professionals are adhering to radiation safety standards. The performance of the panoramic imaging equipment lies at the heart of quality assurance. Regular checks and calibration are essential to ensure that the equipment is operating within specified parameters and delivering accurate and consistent results. This includes verifying the accuracy of the X-ray beam output, image receptor sensitivity, and other technical specifications. Any deviations from the expected performance can lead to suboptimal image quality or excessive radiation doses, compromising both diagnostic accuracy and patient safety. Quality assurance programs also encompass the maintenance and servicing of the imaging equipment. This includes regular cleaning, inspection of components, and replacement of worn-out parts. By ensuring that the equipment is in good working order, QA programs help to prevent malfunctions or breakdowns that could lead to increased radiation exposure or compromised image quality. Imaging protocols, which dictate the technical parameters used during panoramic radiography, are another critical component of quality assurance. These protocols should be based on evidence-based guidelines and best practices, taking into account factors such as patient age, size, and clinical indication. Regular review and optimization of imaging protocols are essential for minimizing patient doses while maintaining diagnostic quality. QA programs can help identify protocols that may be resulting in unnecessarily high radiation doses and recommend adjustments to exposure parameters or imaging techniques. This ongoing process of refinement ensures that imaging protocols are constantly evolving to reflect the latest advancements in radiation safety and dose optimization. While equipment performance and imaging protocols are crucial for radiation safety, the human element also plays a significant role. The knowledge, skills, and practices of dental professionals operating the panoramic imaging equipment can significantly impact patient doses. Quality assurance programs address the human factor by providing regular training and education on radiation safety, imaging techniques, and dose optimization strategies. This empowers dental professionals to make informed decisions regarding imaging protocols, select appropriate exposure parameters, and communicate effectively with patients about radiation safety measures. Furthermore, QA programs can help identify and address any inconsistencies or gaps in staff practices that may be contributing to excessive radiation exposure. By providing constructive feedback and ongoing support, these programs can foster a culture of continuous improvement and ensure that all dental professionals are equipped to deliver safe and effective panoramic imaging services. By optimizing equipment performance, imaging protocols, and staff practices, QA programs can significantly reduce patient radiation exposure, thereby minimizing potential health risks. QA programs help ensure that panoramic images are of high diagnostic quality, facilitating accurate diagnosis and treatment planning. By minimizing the need for retakes due to suboptimal image quality or technical errors, QA programs can improve the efficiency of the imaging process and reduce patient waiting times. By prioritizing patient safety and delivering high-quality imaging services, QA programs can contribute to increased patient satisfaction and trust. QA programs help dental facilities comply with radiation safety regulations and avoid potential legal or financial penalties. Given the critical role of quality assurance in optimizing patient doses and ensuring radiation safety, the implementation of comprehensive QA programs should be considered a mandatory requirement for all dental facilities offering panoramic imaging services. This is particularly important in developing countries like Indonesia, where resources may be limited and access to modern imaging technology may be uneven. By mandating quality assurance programs, regulatory bodies can help establish a minimum standard of care for panoramic imaging, ensuring that all patients, regardless of the facility they visit, receive the safest and most effective imaging services possible. This can contribute to reducing health disparities and promoting equitable access to quality dental care.[18-20]

4. Conclusion

This study has underscored the critical need for enhanced radiation protection practices and dose optimization in panoramic imaging in Makassar. The observed variability in practices and patient doses, often exceeding recommended limits, raises concerns about patient and staff safety. Outdated equipment, inadequate quality assurance, and limited awareness of dose reduction techniques were identified as key contributors to elevated radiation exposure. Therefore, it is imperative to implement comprehensive quality assurance programs, regular equipment maintenance, and continuous professional development to address these issues. By prioritizing radiation safety and adopting best practices, dental facilities in Makassar can significantly reduce radiation risks associated with panoramic imaging, ensuring the well-being of both patients and dental professionals.

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