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Quality assurance of oral and maxillofacial teleradiology: a literature review

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ABSTRACT

Objectives: This article aims to inform dentists and dental specialists about quality assurance in oral and maxillofacial teleradiology as a communication tool between radiologists and colleagues using a teleradiology system.

Review: Teleradiology is a radiological practice that allows the transmission and interpretation of diagnostic images, such as intraoral, extraoral, and CT scans, from different geographic locations. In dentistry, oral and maxillofacial radiologists often interpret these images remotely. To be effective diagnostically, teleradiology must maintain high-quality imaging standards and follow radiological care principles. Quality assurance (QA) plays a vital role in ensuring image clarity, diagnostic accuracy, and patient safety. QA involves implementing standard protocols for image acquisition and transmission using systems such as DICOM (Digital Imaging and Communication in Medicine) and PACS (Picture Archiving and Communication System), under radiologist supervision and with professional

collaboration. Compression formats like JPEG and wavelet, whether lossy or lossless, must be managed properly to avoid image degradation. In clinical dental practice, teleradiology is utilized through teleconsultation, tele-consultancy, and telemanagement, relying on secure communication networks and professional interaction to protect data integrity and confidentiality.

Conclusion: Teleradiology improves access to radiologic interpretation and secondary consultations while offering flexibility in image review. Images can be simultaneously accessed from multiple locations. Successful implementation requires proper compression, stable internet, patient privacy, authentication, and data integrity. With adequate QA measures, teleradiology significantly enhances diagnostic services and patient care outcomes.

Keywords: Quality assurance, oral and maxillofacial, teleradiology

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INTRODUCTION

Oral and maxillofacial radiology services in Indonesia have shown significant progress in recent years, in line with advances in digital imaging technology and electronic communication systems. However, challenges in oral and maxillofacial radiology services continue to persist, particularly regarding geographic access, the availability of imaging equipment, time constraints, and a shortage of qualified personnel. Remote and rural areas still lack adequate access to radiology services, especially outside working hours or in emergency situations. In such circumstances, the involvement of oral and maxillofacial radiologists is crucial. Unfortunately, the number of specialists in this field in Indonesia remains limited and insufficient to meet the growing national demand for diagnostic imaging services.¹

With the development of communication technologies, some of these limitations, particularly

those related to distance and human resources can be addressed through teleradiology, which refers to the electronic transmission of radiographic images for interpretation and consultation at a distance. Teleradiology has been widely applied in general medical practice in many countries, and its use in dental care, especially in oral and maxillofacial radiology, is gaining attention.²

Teleradiology systems have become feasible and increasingly accessible with the adoption of digital imaging, telecommunication infrastructure, and internet connectivity. Today, radiographic images can be transmitted not only across departments within a hospital but also to healthcare providers in different regions or countries, enabling access to expert interpretation from remote areas.³ However, the implementation of teleradiology must adhere to key principles, including patient safety, image and report quality,



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integration with local clinical workflows, access to prior studies, and compliance with radioprotection guidelines.⁴

Despite the technological potential and international adoption of teleradiology, Indonesia currently lacks national guidelines or a standardized framework for implementing quality assurance (QA) in oral and maxillofacial teleradiology. The absence of clear QA protocols creates significant risks, such as inconsistent diagnostic quality, legal uncertainties, and reduced professional accountability. As digital transformation in healthcare accelerates, particularly in the post-COVID-19 era, the urgency to establish QA guidelines tailored to Indonesia's healthcare system has become increasingly critical.⁵

Although international standards and recommendations for teleradiology in medicine are available, they are often not directly applicable to dental practices due to contextual differences in infrastructure, regulation, and clinical needs. To date, there is a significant lack of literature and practical guidance specifically addressing QA in oral and maxillofacial teleradiology in Indonesia. This study aims to address that gap by providing foundational insights into the components of quality assurance necessary to support the safe, reliable, and standardized application of teleradiology in the dental field.

This study aims to provide dental professionals with a comprehensive overview of quality assurance considerations in oral and maxillofacial teleradiology. It seeks to promote awareness and preparedness for the integration of teleradiology as a communication tool between oral radiologists and referring clinicians in Indonesia, thereby improving service quality, accessibility, and diagnostic consistency.

REVIEW

Teleradiology is a branch of telemedicine that

involves the electronic transmission of radiographic images from one location to another for interpretation and consultation by a radiologist. It is especially useful in clinical settings where radiologists are not physically available, such as in remote or rural areas or in emergency departments. Teleradiology enables healthcare providers to access radiologic expertise from a distance and improves the timeliness of radiological reports. In the context of oral and maxillofacial radiology, the purpose of teleradiology includes: providing interpretive services in facilities without onsite dental radiologists, ensuring timely access to imaging diagnosis, supporting clinical decision-making remotely, facilitating second opinions, and interprofessional collaboration.¹

Teleradiology has experienced significant growth due to multiple factors, including increased demand and broader acceptance among healthcare institutions, rising volumes in emergency departments, a shift toward final interpretations rather than preliminary reports, radiology groups outsourcing overflow cases, and a greater need for subspecialty reporting in imaging.² Despite these advantages, several challenges persist, including: Image compression methods that may impact diagnostic quality, internet connectivity, and communication protocols between facilities, concerns regarding privacy, authentication, and data integrity.³

The teleradiology workflow involves two hospitals or health facilities, namely a satellite hospital and a foster hospital. It starts from a request for a radiological examination by the doctor to the patient or the patient's family for the radiological examination to be done by a radiographer. The scanning image in digital format is complete and includes the patient's medical record. Radiological images in digital format are sent by teleradiology to the supporting hospital via the internet.⁶ The clinical workflow can be visualized in Figure 1 and Figure 2.

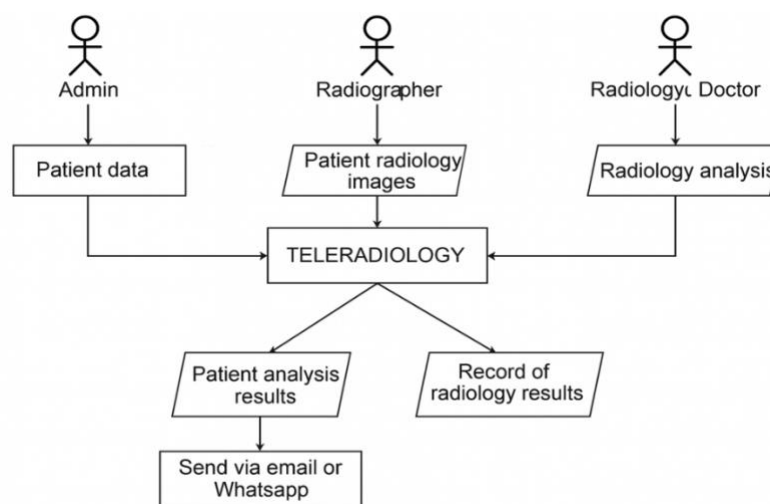


Figure 1. The teleradiology workflow begins with the admin entering patient data into the system, followed by the radiographer uploading the patient's radiology images. The radiologist then analyzes the images through the web-based teleradiology application. The integrated system generates both the patient analysis results, which are sent via email or WhatsApp, and the radiology result records for archiving purposes.

(Source: Adapted from the *Teleradiology Application System Design*, 2025)⁷

High-quality teleradiology must adhere to internationally recognized standards set by the American College of Radiology (ACR), the European Society of Radiology (ESR), and the Royal College of Radiologists (RCR) (UK). These standards cover the full radiology workflow: image acquisition,

transmission, interpretation, report delivery, and legal compliance. Quality Assurance (QA) is a core element and is often enforced through peer-review systems, credentialing protocols, and secure data handling policies.^{2,8}

Table 1. Summary of QA Standards in Teleradiology

QA Component	Description	Standards/Organizations
Image Quality	Diagnostic resolution with minimal compression artifacts	ACR, ESR
Data Security	Encrypted transmission, secured access, and audit logs	ACR, RCR
Radiologist Credentials	Licensed and certified in jurisdiction of image origin	ACR, ESR, Joint Commission
Peer Review	Ongoing case review to monitor performance and error rates	ACR, QA Programs
Legal Compliance	Licensing, malpractice coverage, and regulatory alignment	ESR, RCR, Joint Commission

In dental settings, especially in oral and maxillofacial radiology, teleradiology plays an increasingly vital role in remote interpretation of CBCT (Cone Beam Computed Tomography) scans, supporting diagnostic imaging for surgical and pathological referrals, facilitating continuous education and knowledge sharing among radiologists, and bridging service gaps in underserved regions, including rural and remote areas.¹ Teleradiology not only extends access to expert radiologic services but also strengthens healthcare system efficiency, quality, and equity. Its clinical usefulness in general dental practice has also been demonstrated, highlighting its potential to improve diagnostic accuracy and decision-making in routine dental care.⁹

PACS (Picture Archiving and Communication System)

PACS is a digital system that facilitates the storage, retrieval, and distribution of medical images electronically across healthcare networks. Beyond its technological convenience, PACS plays a vital role in ensuring quality assurance (QA) in teleradiology. It guarantees that diagnostic images are accessible, reliable, and preserved for long-term use without compromising their integrity.¹⁰ Integrated with hospital systems such as RIS (Radiology Information System) and HIS (Hospital Information System), PACS supports QA through: secure storage and backup to prevent data loss, fast retrieval of prior studies for comparative diagnosis, minimized human error via automated image labeling and data linking, and Full traceability for audit and legal compliance.¹⁰ Additionally,

advancements in cloud-based PACS and mobile access have expanded its use in remote interpretation—further aligning with the goals of teleradiology in underserved areas.¹¹

DICOM (Digital Imaging and Communications in Medicine)

DICOM is the global standard for transmitting, storing, and formatting medical images and associated metadata. It ensures interoperability between different imaging modalities, PACS systems, and visualization software from various vendors, making it a foundational element of image standardization and QA in digital radiology.¹² DICOM-compliant images embed structured metadata (e.g., patient ID, modality type, image timestamps), enabling: consistent formatting for accurate viewing and comparison, lossless transmission of image quality over networks, audit trails and data integrity checks for QA verification, facilitation of peer-review and structured reporting, which are critical in standardized diagnosis.¹³

The Role of PACS and DICOM in a QA-Driven Teleradiology System

Together, PACS and DICOM form a unified ecosystem that supports quality and safety in teleradiology practice. While PACS handles data management and workflow continuity, DICOM ensures the accuracy, consistency, and transferability of medical images across systems. This collaboration enables radiologists—especially in remote teleradiology settings—to make accurate diagnoses using high-quality images with reliable provenance.

Table 2. QA Contributions of PACS and DICOM in Teleradiology

Component	QA Function	Benefit
PACS	Secure archiving and real-time access	Minimizes delays and supports timely reads
PACS	Integration with RIS/HIS and audit logs	Reduces manual errors and improves traceability
DICOM	Standardized file format with embedded metadata	Ensures interoperability and accurate review

DICOM	Lossless image encoding and transmission protocols	Maintains diagnostic image quality
Both	Support for structured reporting and case comparison	Enables peer review and consistent QA cycles

PROCESSES IN TELERADIOLOGY

Teleradiology involves a multi-step workflow that transforms raw radiographic data into meaningful diagnostic information shared across distances. Each step plays a critical role in maintaining the quality, safety, and integrity of the service, aligning closely with quality assurance (QA) principles in medical imaging.

Image Digitization

Radiological images must be converted into a digital format before they can be transmitted. Most modern imaging modalities—including CT, MRI, CR, and DR—already produce digital outputs. However, for legacy equipment, digitization may involve laser scanning or CCD digitizers to convert hardcopy films into digital files. Digitized images that comply with DICOM 3.0 standards preserve 12-bit grayscale data (up to 4,096 shades), ensuring diagnostic fidelity and enabling window/level adjustments during interpretation.¹² DICOM-compliant digitization ensures that no image degradation occurs and that diagnostic flexibility is preserved, which is essential for accurate and reproducible interpretations.

File Size and Bandwidth Considerations

Radiological image files are often large (ranging from several megabytes to gigabytes), particularly with modalities like multislice CT or CBCT, which can generate thousands of images in a single study. The transmission of such high-volume data is a longstanding technical challenge in teleradiology. While bandwidth improvements have reduced latency, efficient image transfer remains dependent on proper image optimization strategies.¹⁰ Slow or failed image transfers compromise reporting timelines and may result in incomplete datasets. Efficient handling of file sizes is critical to maintaining timely diagnosis, a cornerstone of clinical quality.

Image Compression

To facilitate storage and faster transmission, image compression is essential. Both lossless and lossy algorithms are widely used in teleradiology. JPEG and wavelet-based compression formats remain common. Studies have shown that well-designed lossy compression can achieve high compression ratios (e.g., 8:1 to 10:1) without compromising diagnostic accuracy, especially when used for anatomical regions with low complexity.¹⁴ Appropriate use of compression algorithms must be balanced with image integrity. QA protocols often require that only validated compression schemes be used and that radiologists confirm the clinical sufficiency of compressed images.

Image Transmission

Teleradiology systems use various networks for transmission, including broadband (DSL, fiber

optics), T1, T3, or secure VPN tunnels. The chosen infrastructure depends on case volume and required response time. Integration with PACS and secure protocols ensures that transmitted data remains intact and confidential.¹¹ Secure, stable transmission networks reduce image corruption and unauthorized access, both of which are QA-critical metrics for patient safety and legal compliance.

Image Interpretation

Radiologists typically interpret teleradiology images on certified workstations integrated with PACS. These systems allow for advanced manipulation (e.g., 3D reconstruction, zoom, contrast enhancement) and structured reporting. Some platforms allow remote subspecialists to log in and interpret cases in real-time or asynchronously.^{10,13} Accurate interpretation depends not only on image quality but also on the tools and calibration of viewing systems. QA standards require consistency in viewing conditions, monitor resolution, and radiologist credentialing.

Reporting

Reports are generated using standardized formats and transmitted back to referring physicians through secure means such as email, web portals, or integrated EHR systems. Automation—such as voice-to-text dictation or template-based reports—helps reduce turnaround time and transcription errors.¹³ Structured, timely, and traceable reports are essential components of clinical governance. QA systems track turnaround time and ensure completeness and clarity in radiologic communications.

Security Systems

Teleradiology workflows must comply with data protection laws and ethical standards. Secure systems ensure confidentiality (only authorized access), integrity (unaltered data), and availability (system uptime) of patient information. Encryption protocols, digital signatures, and access audits are all part of a robust security infrastructure.¹⁵ Security directly impacts quality by protecting patient trust and maintaining legal compliance. QA standards require that all transmission and storage be encrypted and audit-logged to prevent breaches.

DISCUSSION

This review highlights that teleradiology has evolved into a strategic tool in oral and maxillofacial radiology services, particularly in improving diagnostic access in areas with limited human resources and infrastructure. However, its implementation still faces fundamental challenges that affect service sustainability and quality, especially in terms of quality assurance (QA).

One of the primary findings is the mismatch

between international QA standards and local practice. Guidelines from organizations such as the American College of Radiology (ACR), the European Society of Radiology (ESR), and the Royal College of Radiologists (RCR), although comprehensive, have not been widely adopted in the Indonesian dental context. This creates gaps in regulatory frameworks, professional accountability, and health information system integration. Santos et al. (2022) emphasized that without comprehensive QA, teleradiology could increase the risk of diagnostic errors, especially when interpretations are performed in inconsistent viewing conditions or using images compressed with non-validated algorithms.¹⁶

Another significant challenge lies in the technical complexity of maintaining image integrity throughout acquisition, transmission, and interpretation processes. Image quality is often compromised by suboptimal compression algorithm selection, particularly in facilities with limited bandwidth. Logeswaran (2019) warned that the use of unstandardized lossy compression could obscure critical diagnostic details, especially in CBCT evaluations or small maxillofacial lesions.¹⁷

Moreover, communication infrastructure and software licensing costs remain major barriers. Unequal internet access and the high price of PACS and DICOM software licenses significantly hinder the equitable adoption of teleradiology across Indonesia. Studies by Haleem et al. (2021) and Hariri (2020) stressed that information technology systems and data security are key determinants of sustainable teleradiology systems.^{18,19}

From a human resources perspective, the low ratio of oral and maxillofacial radiologists to national service demands results in heavy workloads and potential decreases in interpretation accuracy. Choi et al. (2018) emphasized the importance of continuous education and peer-review mechanisms as essential QA strategies to maintain professional standards in dental teleradiology practice.⁹

Strategic solutions to overcome QA challenges, local adaptation of international standards is required. QA guidelines from ACR/ESR need to be adapted into national policies through collaboration between the Indonesian dental radiology association, MOH, and educational institutions. Development of QA standards-based training modules should also be prioritized. The development of a cloud-based QA system, namely, utilizing cloud-PACS with end-to-end encryption, as well as automatic integration between PACS-RIS-HIS, can improve the efficiency and security of image transmission. Research by Pierce (2022) and Lucas et al. (2020) shows that cloud-based QA systems are effective in ensuring data auditing and enabling cross-site interpretation without quality degradation.^{20,21} Validation of local compression algorithms. There should be a list of nationally validated medical image compression algorithms based on the anatomical context of the maxillofacial area. This validation should include a double-reading study to measure inter-observer

agreement. Capacity building through distance learning schemes, such as e-learning systems, webinars, and case-based simulations can be used to accelerate the distribution of teleradiology QA skills for general dentists and novice radiologists, and Implementation of a QA audit and feedback loop system, so Each teleradiology unit should have a radiologist performance evaluation mechanism, report turnaround time tracking, and a referring clinical party complaint system.

CONCLUSION

Teleradiology enhances access to radiological interpretation and supports timely, collaborative diagnostics across multiple locations. It improves efficiency and care quality when supported by stable internet, secure data transmission, validated compression, and proper QA protocols. In Indonesia, successful implementation requires adapting international QA standards into national guidelines, expanding internet infrastructure, subsidizing PACS/DICOM systems for remote areas, and providing training through e-learning. Establishing regional teleradiology hubs and audit mechanisms will further support sustainable, equitable radiology services nationwide.

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FOOTNOTES

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