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ARTIFICIAL INTELLIGENCE IN DENTISTRY AND MAXILLOFACIAL DIAGNOSTICS: CLINICAL APPLICATIONS OF AI-BASED RADIOLOGY AND ELASTOGRAPHY

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Abstract
In contemporary medical practice, artificial intelligence (AI) is transforming traditional diagnostic approaches, offering innovative solutions to enhance the accuracy and efficiency of clinical research. Dentistry and maxillofacial diagnostics represent promising areas for the application of machine learning and computer vision technologies.

Keywords: artificial intelligence (ai), dentistry, radiology, maxillofacial diagnostics, machine learning, neural networks

Introduction

Advances in artificial intelligence (AI) are reshaping diagnostic workflows across healthcare, and dentistry is no exception. In recent years, AI algorithms – particularly machine learning and deep learning models – have demonstrated impressive capabilities in image analysis, decision support, and pattern recognition in medicine. Dentistry generates a wealth of data (radiographs, 3D scans, clinical records, etc.), often exceeding what a practitioner can thoroughly analyze during routine care. AI tools offer a means to integrate and interpret this information efficiently, potentially detecting subtle pathological signs (e.g. early caries or bone loss) that might be overlooked by the human eye (Luke & Rezallah, 2025). Early studies have already shown that AI can match or even exceed clinicians in certain diagnostic tasks, such as identifying dental caries on radiographs. Moreover, beyond conventional radiology, AI is being applied to emerging imaging modalities like elastography (imaging tissue elasticity) to improve the diagnosis of soft-tissue lesions in the maxillofacial region. This article reviews the clinical applications of AI-based radiology and elastography in dental and maxillofacial diagnostics. We discuss three representative AI systems or approaches – two in dental radiographic analysis and one in elastography – and compare their technologies, diagnostic performance, and integration into clinical workflows. We further address how AI can be incorporated into the dental practice and highlight current challenges and future directions for this rapidly evolving field.

AI in Dental Radiology Diagnostics

Digital radiography is fundamental in dentistry for detecting pathologies like caries, periapical lesions, and periodontal bone loss. AI has increasingly been leveraged to enhance radiological diagnostics in both two-dimensional (intraoral radiographs, panoramic X-rays) and three-dimensional imaging (cone-beam CT scans). Modern AI systems typically use convolutional neural networks (CNNs) trained on thousands of annotated dental images to recognize features of disease. In fact, a 2025 systematic review found that most AI models for caries detection on X-rays achieved high sensitivity and specificity, often comparable to experienced dentists. For example, one randomized trial reported an AI-based software could diagnose dental caries on intraoral radiographs with 88% sensitivity and 91% specificity, slightly outperforming human examiners (84% and 88% respectively) (Das et al., 2024). Such consistency and accuracy underscore AI's potential to aid in early detection of common dental diseases.

Several AI-driven radiology tools have emerged commercially. Diagnocat (DGNCT LLC) is a cloud-based AI system that analyzes 2D and 3D dental images and automatically highlights a range of findings on dental radiographs and cone-beam CT (CBCT) scansmdpi.com. Clinically, Diagnocat can identify dental caries, periapical radiolucencies (suggestive of endodontic lesions), impacted teeth, sinus pathoses, and other abnormalities, generating an annotated report for the dentist's review. Studies have evaluated Diagnocat's performance: in one study using panoramic radiographs, this AI system showed high accuracy (~90.7%) in detecting the presence of endodontic treatments (root canal fillings) on teeth. Another investigation found that Diagnocat-assisted clinicians detected significantly more lesions on CBCT scans than those working unaided – with AI assistance improving diagnostic sensitivity from ~77% to ~85%. These results suggest that AI can serve as a reliable "second pair of eyes" for dental radiologists, improving the detection of subtle findings and reducing diagnostic oversight (Ezhov et al., 2021).

Another notable platform is DTX Studio Clinic (by Dexis/Envista), an integrated dental imaging software suite that incorporates AI for radiographic analysis. DTX Studio can organize and display a patient's 2D and 3D images (from intraoral X-rays to CBCT) and uses algorithms to automatically recognize anatomical structures and label tooth numbers (MagicSort™), as well as screen for common pathologies on radiographs (e.g. dental caries, calculus, periapical lesions). Its AI "Findings" tool can highlight up to six key dental findings on an X-ray for clinician review, thus streamlining the diagnostic process. A unique aspect of DTX Studio is its tight integration into clinical workflows – linking imaging directly with implant planning and other treatment modules. While detailed performance metrics of DTX's AI have not been extensively published in peer-reviewed studies, it exemplifies the trend of major dental software platforms embedding AI to enhance efficiency and diagnostic consistency. Early reports indicate such systems can expedite image interpretation and ensure that obvious pathologies are not missed, effectively functioning as a real-time decision support. However, the accuracy of these proprietary tools still needs rigorous independent validation. Researchers have pointed out that many popular dental AI applications (including some already in wide use) lack published clinical evaluations and may be

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webofjournals.com/index.php/5

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cleared for use in certain regions without comprehensive efficacy studies. This has prompted calls for more transparency and scientific validation of AI algorithms in dentistry (Lal et al., 2025). Notably, regulatory bodies are beginning to assess these tools: for instance, the FDA has cleared certain dental AI software for specific diagnostic tasks (such as *Overjet* for detecting caries and quantifying bone loss on radiographs), whereas others like Diagnocat currently remain non-FDA-cleared, limiting them to research or markets outside FDA oversight. Moving forward, obtaining regulatory approval and demonstrating real-world reliability will be critical for AI radiology systems to gain the full trust of dental professionals and to be adopted broadly in practice.

AI in Elastography for Maxillofacial Diagnostics

While radiographs and CBCT focus on hard tissues (teeth and bone), elastography is an imaging technique valuable for soft tissue evaluation in the oral and maxillofacial region. Ultrasound elastography measures the stiffness or elasticity of tissues – for example, distinguishing a fibrous lesion from a fluid-filled cyst, or benign from malignant tumor, based on how soft or hard the tissue is. It has shown promise in diagnosing lesions in salivary glands, tongue and oral mucosa, and temporomandibular joint (muscle or disc disorders) by providing information beyond conventional ultrasound images. However, interpreting elastographic images can be subjective and operator-dependent, requiring experience to identify meaningful patterns in stiffness maps. This is where AI can play a transformative role. Machine learning algorithms can be trained on elastography datasets to automatically quantify tissue stiffness and classify lesions more objectively. AI analysis of elastography aims to reduce variability between operators and improve diagnostic accuracy by detecting subtle differences in elasticity that correlate with pathology.

In the context of maxillofacial diagnostics, AI-enhanced elastography is still an emerging field, but initial studies are encouraging. For example, in thyroid nodule evaluation (a concept transferable to salivary gland tumors), AI models have been used to combine B-mode ultrasound and elastography data to distinguish benign from malignant nodules. In one study, a machine learning classifier achieved an area-under-curve (AUC) of 0.94 in identifying thyroid cancers, slightly outperforming expert radiologists interpreting the images conventionally. This demonstrates AI's capability to match or exceed expert performance in soft-tissue lesion diagnosis. Similarly, researchers have applied deep learning to oral cancer screening: by feeding elastography images of oral mucosal lesions into neural networks, the AI could potentially flag areas suspicious for malignancy, helping clinicians prioritize biopsies. Elastography combined with AI has also been explored for assessing muscle and joint conditions – for instance, evaluating the masseter muscle's stiffness in bruxism or temporomandibular disorders with automated image segmentation and analysis (Al-Ekrish et al., 2020). The general trend is that AI can extract quantitative features (stiffness gradients, patterns) from elastograms that may not be apparent to the human observer, thereby improving diagnostic objectivity.

That said, AI in elastography for dentistry is largely in the research or prototypical stage. Unlike dental radiology AI, there are not yet widely available commercial elastography-AI tools specifically for dental practice. Limitations include the need for sufficient high-quality training data (ultrasound elastography datasets of head and neck lesions are limited), variability in ultrasound machines and settings, and the requirement of expert annotations for ground truth. Nonetheless, ongoing studies in oncology and oral medicine continue to refine these models. As these techniques mature, we can expect AI-assisted elastography to become a valuable adjunct for oral and maxillofacial surgeons – for example, in preoperative tumor evaluation (to differentiate malignant tumors from benign lesions or cysts by stiffness) and in monitoring treatment responses (where changes in tissue elasticity over time could indicate fibrosis or recurrence). Ultimately, integrating AI with elastography could enhance the diagnostic confidence for soft tissue lesions in the head and neck, similar to how AI is enhancing hard-tissue imaging in dentistry.

Comparison of AI Systems in Dental Diagnostics

To better understand the landscape of AI applications, Table 1 compares the three main AI systems/approaches discussed – two focused on dental radiographic analysis (Diagnocat and DTX Studio Clinic) and one on ultrasound elastography – in terms of their technology, clinical capabilities, and limitations:

Table 1. Comparison of Representative AI Systems in Dentistry

AI System / Approach	Type & Modality	Clinical Capabilities	Key Features	Current Limitations
Diagnocat (AI radiology tool)	*Deep-learning software for 2D/3D dental imaging* (panoramic X-rays, intraoral radiographs, CBCT scans)	– Automatic detection of dental caries, periapical lesions, periodontal bone loss, impacted teeth, etc. on radiographic images. – Generates an AI-driven radiology report highlighting suspected pathologies and existing restorationsmdpi.com.	– Cloud-based platform; uses CNN models trained on large dental image datasets. – Provides annotated images and confidence scores for findings, aiding as a second-opinion for dentists. – Continuously updates via machine learning on new data.	– Requires high-quality images; performance can drop with low-resolution or artifact-laden scans. – Not yet FDA-clearednature.com, limiting official clinical use in some regions. – Does not incorporate clinical context (findings are based solely on image data, which may lead to false positives that need dentist interpretation).
DTX Studio Clinic (Envista/Dexis)	*Integrated dental imaging suite with AI features* (panoramic and intraoral X-rays; CBCT)	– Consolidates all patient images (2D & 3D) for diagnosis and treatment planning (e.g. implant planning). – AI-driven tooth identification (automatic numbering of teeth on images) and preliminary screening for common pathologies on radiographs (e.g.	– Seamless integration into clinical workflow software; unified interface for imaging and analysis. – AI "findings" tool built into imaging viewer highlights up to six potential issues on X-rays for clinician review. – Tools like MagicSort™ automate tasks (e.g., sorting and orienting radiographs), saving time.	– Limited independent studies on diagnostic performance (most claims are from the manufacturer). – AI detection is restricted to a predefined set of pathologies (may not catch unusual conditions). – Being a commercial

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		caries, calculus, apical radiolucencies).		platform, its AI algorithms are proprietary; transparency in how findings are generated is limited. – Requires purchase of the specific software ecosystem; interoperability with other systems can be an issue.
AI-based Elastography (research approach)	*Machine learning applied to ultrasound elastography* (ultrasound imaging of soft tissue stiffness)	– Assists in differentiating benign vs. malignant lesions in salivary glands, lymph nodes, etc., by analyzing stiffness patterns. – Quantifies tissue elasticity for conditions like oral submucosal fibrosis or TMJ disorders, improving objective assessment. – Could flag areas of abnormal stiffness in oral soft tissues (tongue, floor of mouth) for early cancer detection.	– Utilizes radiomic features and deep neural networks to analyze elastography maps, providing risk scores or probability of malignancy. – Can reduce operator variability by automatically interpreting elastogram color maps and measurementsfrontiersin.org. – Non-invasive and adds functional information (tissue hardness) beyond traditional imaging.	– Mostly in experimental or pilot stages; not widely available as a turnkey clinical tool. – Performance can vary with ultrasound technique and machine settings; requires standardization. – Needs large datasets with biopsy-confirmed outcomes for training, which are currently limited in the oral domain. – Integration into clinical workflow is unproven; radiologists/dentists would need training to trust and use these AI elastography analyses.

As shown in Table 1, AI systems in dentistry can differ considerably in focus. Diagnocat and similar tools concentrate on hard-tissue imaging (radiographs/CBCT) and are already yielding high accuracy in detecting dental pathologiesmdpi.com. DTX Studio represents how AI is being embedded into dental software suites to streamline image management and preliminary diagnoses. Meanwhile, AI applied to elastography offers a glimpse into the future of soft-tissue diagnostics, tackling problems that traditional dental imaging doesn’t address. Each system has unique features — from Diagnocat’s comprehensive automated reports to DTX’s workflow integration and the quantitative tissue analysis of elastography AI. At the same time, each comes with limitations, whether technical (e.g., image quality dependence), regulatory, or the need for further clinical validation.

Diagnostic Accuracy: AI vs. Human Clinicians

A central question for any medical AI is how its diagnostic performance compares to that of human experts. In dentistry, numerous studies have now directly pitted AI algorithms against experienced dentists or radiologists for tasks like detecting carious lesions, identifying endodontic pathology, or interpreting scans. Overall, the evidence suggests that AI can perform at least on par with clinicians for many narrow diagnostic tasks, and in some cases offers superior consistency or sensitivity. Figure 1 illustrates a representative comparison of diagnostic accuracy between an AI system and human dentists, based on a recent controlled study of caries detection from radiographs (Das et al., 2024). In that randomized trial, the AI software slightly outperformed the dentists in all measured metrics – sensitivity, specificity, and overall accuracy – demonstrating how modern algorithms can closely mimic expert decision-making in radiographic interpretation.

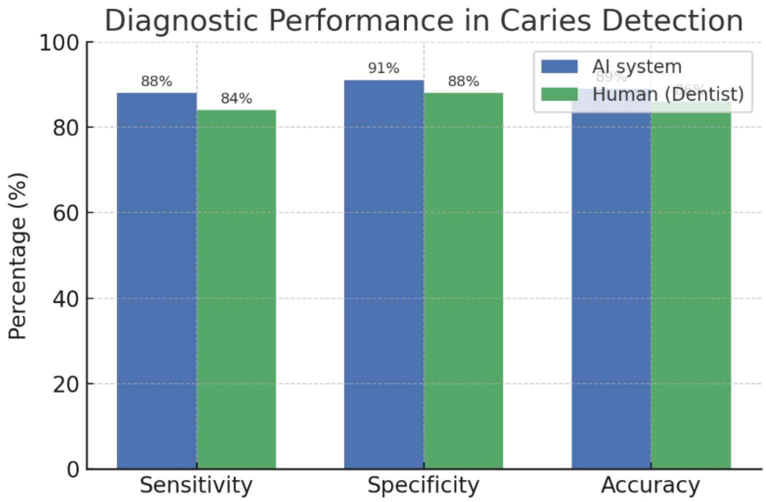

Figure 1: Comparative diagnostic performance of an AI system vs. human dentists in detecting dental caries from radiographs. This chart is based on results from a randomized controlled trial by Das et al. (2024) in which an AI deep learning model analyzed 200 intraoral radiographs for cavities and was benchmarked against evaluations by experienced clinicians. The AI achieved 88% sensitivity, 91% specificity, and 89% overall accuracy, compared to 84%, 88%, and 86% for human interpretation. These results fall in line with other studies and meta-analyses indicating that AI algorithms can identify pathologic features on dental X-rays with a diagnostic accuracy comparable to skilled practitioners. Importantly, AI systems tend to be very consistent in their output (given the same input), whereas human diagnoses can vary between examiners. This consistency can reduce missed lesions – for example, the AI might catch a small incipient cavity that one dentist overlooked – thereby potentially raising the overall sensitivity of diagnostics in practice. On the other hand, human providers bring clinical context and judgment to the table, which AI currently lacks; thus an ideal scenario is a synergy where the AI handles initial screenings or measurements and the clinician makes the final call, especially on ambiguous cases.

Regulatory and Ethical Considerations: As AI becomes integrated into diagnostics, regulatory bodies are developing frameworks to ensure safety and efficacy. Receiving FDA clearance or other regulatory approvals provides some assurance that an AI tool meets basic performance standards. For example, as noted, Overjet's AI for detecting radiographic bone loss and caries is cleared for clinical use, and another system, Denti.AI, has approval for certain documentation and

Web of Medicine: Journal of Medicine, Practice and Nursing
webofjournals.com/index.php/5

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radiographic analysis features. These approvals require evidence of accuracy and consistency. In contrast, tools without such clearance (e.g., Diagnocat as of 2025) are usually restricted to investigational use or deployment in markets with less stringent oversight. Beyond accuracy, there are ethical issues: ensuring patient data privacy when using cloud-based AI, obtaining informed consent if AI is used in diagnosis, and addressing liability (who is responsible if the AI misses a cancer on a scan?). Professional organizations are beginning to draft guidelines on the responsible use of AI in dentistry (e.g., the ADA's 2023 standards for AI ethics in dental practice), emphasizing that AI should augment but not replace clinician judgment and that safeguards must be in place to prevent harm from AI errors (Lal et al., 2025).

Technical Hurdles: From a development standpoint, dental AI faces some unique technical hurdles. Dental imaging data can be highly variable (different X-ray angles, patient anatomies, image resolutions), and AI models must be robust to such variability. Additionally, certain conditions are relatively rare (e.g., tumors in the jaw), making it hard to gather enough examples for the AI to learn them well – this could lead to biases where the AI is very good at finding common issues like cavities but poor at recognizing less common pathologies. Ongoing improvements in data augmentation, federated learning (where models learn from multi-center data without compromising privacy), and inclusion of multi-modal data (combining radiographs with, say, intraoral photos or patient history) may help surmount these issues. Another frontier is reducing AI "black box" opacity: providing explanations for why the algorithm flagged a certain area, which can increase clinician confidence in the system. Techniques in explainable AI are being researched so that, for instance, an AI could highlight the specific pixel pattern or features that led it to label an area as carious.

Looking ahead, the future of AI in dental and maxillofacial diagnostics is bright. We can expect ever more sophisticated algorithms that not only detect disease, but also predict outcomes and suggest optimal treatment approaches (e.g., AI that can analyze a radiograph and predict the progression rate of a carious lesion, or the likelihood that a certain impacted tooth will cause problems). Integration with other technologies is on the horizon: for example, coupling AI diagnostics with 3D printing to design surgical guides or restorations immediately after a scan, or using AI in augmented reality glasses to guide a dentist during an procedure by highlighting anatomical landmarks in real-time. AI might also play a role in population oral health – analyzing large sets of images from dental clinics to identify public health trends or to triage cases remotely (teledentistry with AI screening). In the realm of elastography and beyond, as imaging modalities like optical coherence tomography (OCT) and MRI become more prevalent in oral diagnostics, AI will surely be applied there too, potentially enabling earlier detection of oral cancers or precancerous changes through pattern recognition on a microscopic level (Xie et al., 2024).

In summary, the challenges of validation, integration, and regulation are significant but are being actively addressed. Collaboration between AI developers, dental clinicians, and regulatory bodies will be essential to ensure that these technologies develop in a patient-centric, safe manner. If successful, AI stands to become an indispensable part of dental diagnostics – not as a replacement for the dentist, but as a powerful extension of the dentist's capabilities, improving accuracy, efficiency, and ultimately, patient oral health outcomes.

Conclusion

Artificial intelligence is poised to revolutionize dentistry and maxillofacial diagnostics by augmenting the clinician's ability to detect and diagnose diseases from medical images. In radiology, AI algorithms can swiftly analyze dental radiographs and CBCT scans, flagging cavities, periodontal bone loss, periapical pathology and more with accuracy on par with expert clinicians. In elastography and other advanced imaging, AI offers a means to quantify and interpret complex data (like tissue elasticity), potentially catching pathologies that would be challenging to discern otherwise. The clinical applications discussed – from AI-powered radiology tools like Diagnocat and DTX Studio, to experimental AI-elastography techniques – demonstrate that AI can improve diagnostic consistency and help identify problems earlier, which is critical for prevention and effective treatment in dentistry. Integrating these tools into practice via a well-designed workflow allows dentists to save time and reduce diagnostic errors while still retaining full control over patient care decisions.

However, the journey from promising technology to standard-of-care is still underway. Dentists must be aware of AI's current limitations: these systems work best as assistive aids and are not infallible. Rigorous validation studies and regulatory oversight are needed to ensure AI tools truly benefit patients and do not introduce new risks. Moreover, practitioners will require training to interpret AI results and to manage any ethical or legal implications. With continued research and refinement, AI will undoubtedly become more accurate, explainable, and versatile. In the near future, we can expect AI to be seamlessly embedded in dental practice management software, imaging devices, and even patient-facing apps – forming a digital health ecosystem where clinical decisions are informed by vast data and intelligent algorithms. Such a future holds great promise: a dental healthcare model that is more predictive, personalized, and preventive, where diseases are caught in their infancy and treatment is optimized for each individual. Achieving this will require a thoughtful blend of technological innovation and clinical wisdom. In conclusion, AI in dentistry and maxillofacial diagnostics is not merely a theoretical concept but an evolving reality – one that, with proper implementation, stands to enhance diagnostic precision and improve the oral health of patients worldwide.

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