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# Integrating artificial intelligence in healthcare: applications, challenges, and future directions

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**ABSTRACT**

Artificial intelligence (AI) has demonstrated remarkable potential in transforming medical diagnostics across various healthcare domains. This paper explores AI applications in cancer detection, dental medicine, brain tumor database management, and personalized treatment planning. AI technologies such as machine learning and deep learning have enhanced diagnostic accuracy, improved data management, and facilitated personalized treatment strategies. In cancer detection, AI-driven imaging analysis aids in early diagnosis and precise treatment decisions. In dental healthcare, AI applications improve oral disease detection, treatment planning, and workflow efficiency. AI-powered brain tumor databases streamline medical data management, enhancing diagnostic precision and research outcomes. Personalized treatment planning benefits from AI algorithms that analyze genetic, clinical, and lifestyle data to recommend tailored interventions. Despite these advancements, AI integration faces challenges related to data privacy, algorithm bias, and regulatory concerns. Addressing these issues requires improved data governance, ethical frameworks, and interdisciplinary collaboration among healthcare professionals, researchers, and policymakers. Through comprehensive validation, educational initiatives, and standardized protocols, AI adoption in healthcare can enhance patient outcomes and optimize clinical decision-making, advancing the future of precision medicine and personalized care.

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Artificial intelligence; cancer detection; brain tumour databases; dental healthcare; personalized treatment planning

**PLAIN LANGUAGE SUMMARY**

This article explores how artificial intelligence (AI) is being used to improve healthcare. AI can analyze large amounts of data quickly, helping doctors detect diseases earlier, plan treatments more accurately, and manage patient records more efficiently. It is particularly useful in cancer diagnosis, dental health, brain tumor analysis, and personalized treatment planning. For example, AI tools can examine medical images to spot tumors or oral issues that may be missed by the human eye, and machine learning algorithms can suggest treatment options based on a patient's unique history and health data. The study highlights successful applications of AI, such as using advanced image recognition to identify cancer, optimizing dental procedures, and improving brain tumor classification. Despite these benefits, challenges remain. These include concerns over data privacy, the fairness and transparency of AI decisions, the need for high-quality training data, and ensuring that medical professionals are trained to use AI effectively. The authors recommend stronger ethical guidelines, better education for healthcare workers, and improved validation of AI systems. With ongoing research and careful integration, AI has the potential to make healthcare more precise, efficient, and personalized, ultimately improving outcomes for patients and supporting doctors in delivering high-quality care.

**ARTICLE HIGHLIGHTS**

- Comprehensive Review of AI in Healthcare: This paper presents an in-depth analysis of AI applications across major medical domains, including cancer detection, dental healthcare, brain tumor management, and personalized treatment planning.
- Advanced AI Models and Techniques Explored: Cutting-edge AI architectures such as CNNs, SqueezeNet, InceptionResNet-V2, CR-Net, and the Modified Whale Optimization Algorithm are evaluated for their roles in improving diagnostic accuracy and treatment outcomes.

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- Enhanced Diagnostic Capabilities: AI technologies are shown to significantly improve early disease detection and classification accuracy, particularly in oncology and dental medicine, with accuracy rates exceeding 95% in some studies.
- Development of AI-Driven Medical Databases: The use of AI in creating and managing brain tumor databases enables more accurate tumor localization, segmentation, and classification, supporting both clinical decision-making and research.
- Personalized Medicine and Predictive Analytics: AI facilitates tailored treatment planning by analyzing genetic, clinical, and lifestyle data, enhancing therapeutic precision and patient-specific interventions.
- Ethical and Practical Challenges Addressed: The study highlights ongoing concerns with data privacy, algorithmic bias, model explainability, and regulatory compliance, while proposing strategies for ethical AI integration into clinical workflows.

## 1. Introduction

Artificial intelligence (AI) refers to the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using it), reasoning and self-correction [1]. AI can be categorized into narrow AI, which is designed for a particular task, and general AI, which aims to mimic human cognitive abilities across a wide range of tasks. In the context of the Fourth Industrial Revolution (IR4.0), artificial intelligence (AI) is indispensable due to its trans formative capabilities across different industries [2]. AI enables the automation of tasks, leading to enhanced efficiency and productivity in a digitalized and interconnected landscape. By analyzing vast amounts of data collected from sensors and IoT products, AI provides valuable insights that inform strategic decision-making and drive innovation. Data collected from sensors and IoT (Internet of Things) products are vast and complex due to the sheer volume, variety, and velocity at which they are generated [3,4]. These data streams encompass diverse types of information, ranging from environmental conditions and equipment status to user interactions and preferences which required precise data analysis to enable a better decision making [5–8]. Additionally, IoT devices continuously produce data in real-time, creating a constant flow of information that traditional analytic methods struggle to handle effectively [9–12]. Hence, AI is indispensable for analyzing this wealth of data and deriving actionable insights because it can efficiently process and interpret complex patterns and correlations that may not be apparent to human analysts [1]. By leveraging AI algorithms, organizations can uncover hidden trends, predict future events, and make data-driven decisions in real time, thereby maximizing operational efficiency, optimizing resource utilization, and enhancing overall performance in an organization [5–7]. Hence, AI facilitates personalization by tailoring experiences based on individual preferences, thereby improving the quality of customer services especially in industry where it revolves around human wellbeing.

One of the key industries centered around human wellbeing is the healthcare industry where AI application is revolutionizing industry, specifically in medical diagnosis by using smart medical devices (IoT) to collect real-time patient data, which AI then analyzes to detect patterns, predict diseases, and assist doctors in making faster, more accurate diagnoses. The incorporation of AI technologies in the healthcare sector has shown substantial enhancements in effectiveness, precision, and patient results [13]. Artificial intelligence (AI) tools are becoming more commonly utilized in medical diagnosis and pathology, streamlining tasks with enhanced velocity and accuracy. These advancements have indeed resulted in the transformation of healthcare systems, improving efficiency, quality, and patient care. AI is used in medical diagnosis in different fields like radiology, pathology, ophthalmology, and oncology [14]. Artificial intelligence (AI) is crucial in predicting diseases by using extensive datasets to detect patterns and risk factors. This allows for proactive interventions to be implemented. In addition, diagnostic tools driven by artificial intelligence improve the precision and effectiveness of identifying a wide range of conditions, including both common ailments and rare diseases.

In addition to diagnosing medical conditions, AI speeds up the process of discovering new drugs by quickly screening molecules and optimizing treatment plans. The increasing dependence on AI technologies in healthcare is apparent, as AI models consistently attain or exceed human performance levels in medical tasks. AI has a wide-ranging impact that encompasses diagnosis, treatment, and patient management, covering everything from prevention to after-care. Although there has been significant advancement, the ethical concerns for a strong legal structure. Ensuring the responsible and ethical integration of AI technologies in medical diagnosis and beyond is crucial as AI continues to revolutionize healthcare delivery. This review explores the revolutionary application of AI, emphasizing its significant influence on medical diagnostics and the delivery of healthcare. Figure 1 depicts a few main applications of artificial intelligence (AI) in the healthcare industry.

AI has demonstrated its indispensability in various healthcare scenarios, such as result analysis, disease treatment, and patient outcome prediction, hence it is embedded in healthcare services to enable more efficient methods for cancer detection, enable the development of extensive healthcare databases, enable optimum personalized treatment planning and providing a better healthcare service particularly in dental care [15]. AI systems also have been extensively studied and researched in various fields such as prevention, diagnosis, drug design, and after-care. The incorporation of artificial intelligence (AI) technologies in healthcare systems has fundamentally transformed the approach that medical professionals take toward diagnosis, treatment, and patient care. Over the past few years, there has been a growing focus on incorporating AI into medical diagnosis, resulting in significant advancements in the field. AI tools have played a crucial role in identifying and diagnosing medical conditions at an early stage, creating treatment plans, and predicting the outcomes of various diseases. The significance of domain expertise in establishing user trust and the value of initial interactions with intelligent systems have been highlighted, emphasizing the requirement for seamless integration of AI models to aid end-users in accomplishing their objectives.

Despite the significant advancements in the integration of AI within the healthcare sector, it is crucial to recognize the persistent challenges and ethical considerations that must be addressed to ensure its responsible and effective implementation. One of the primary concerns revolves around the ethical and legal implications of deploying AI-driven technologies in medical diagnosis and treatment. The potential risks associated with patient confidentiality, data privacy, and the security of sensitive medical information remain pressing issues, as AI systems often rely on vast amounts of personal health data for training and decision-making. The possibility of data breaches, unauthorized access, or misuse of patient records underscores the importance of implementing robust cybersecurity measures and stringent data protection protocols. Additionally, the ethical concerns surrounding AI decision-making, such as algorithmic bias, accountability, and transparency in AI-generated diagnoses, raise questions about trust and reliability in clinical settings. To address these challenges, there is a growing need for well-defined ethical guidelines and a comprehensive legal framework that governs the development, deployment, and regulation of AI applications in healthcare. Establishing clear

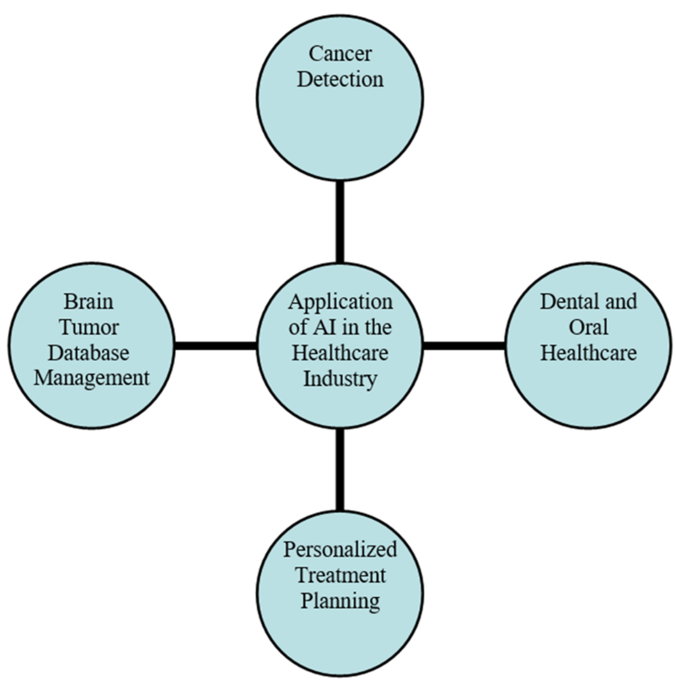


Figure 1. Primary uses of artificial intelligence (AI) in the healthcare industry. This schematic illustrates the key applications of AI technologies within healthcare, including cancer detection, dental healthcare, brain tumor database management, and personalized treatment planning. Each application is highlighted with a representative icon and brief description to demonstrate the diversity of AI implementations across diagnostic, treatment, and data management functions.

policies and regulations can help mitigate risks, ensure compliance with patient rights, and foster the ethical use of AI in medical diagnosis, ultimately enhancing patient trust and safety in AI-driven healthcare solutions [16]. Henceforth, this review paper aims to provide a comprehensive overview of the development of AI in enhancing medical diagnosis within the healthcare industry while also discussing the existing challenges and prospects of AI in medical diagnosis. This study adopts a narrative literature review approach to examine the applications, challenges, and future directions of AI in medical diagnostics. Relevant literature was identified through peer-reviewed journals, recent systematic reviews, and clinical studies spanning 10 years from 2016 to 2025, focusing on high-impact areas such as cancer detection, dental healthcare, brain tumor management, and personalized treatment planning. Articles were selected based on their relevance to the theme of AI integration in medical diagnostics and their contribution to understanding technological, clinical, and ethical implications. The literature was synthesized thematically across domains, highlighting key applications, AI techniques employed, clinical benefits, and associated challenges. The review was collaboratively conducted by multiple authors, each contributing to data curation, analysis, and validation.

## 2. AI detection for cancer detection

The integration of AI technology, particularly machine learning and deep learning, has significantly enhanced the accuracy and efficiency of cancer diagnosis. AI is widely used across various domains in oncology, including medical imaging analysis, disease diagnosis, and risk prediction, leading to improved early detection and treatment outcomes as shown in Table 1. Research has demonstrated AI's effectiveness in diagnosing multiple types of cancer, such as breast, lung, colorectal, and gastric cancer, showcasing its broad applications in oncology.

A key area where AI has been instrumental is medical imaging, where it aids in the identification and classification of cancerous tissues, such as colorectal polyps, leading to earlier and more precise interventions. Furthermore, AI-driven radiomics and deep learning techniques have shown remarkable success in differentiating parotid gland tumors, improving diagnostic accuracy and reducing misclassification. The application of AI in magnifying narrow-band imaging for early gastric cancer detection further highlights its potential in overcoming diagnostic challenges and enhancing patient outcomes.

AI has also played a pivotal role in optimizing decision-making for healthcare professionals by reducing diagnostic errors and increasing efficiency [17,18]. Studies have shown that AI-assisted tools have significantly lowered misdiagnosis rates in conditions such as metastatic breast cancer and colorectal cancer polyps, with accuracy levels surpassing 98% [19]. These advancements not only improve patient survival rates but also alleviate the workload on medical practitioners, enabling more precise and timely interventions.

Additionally, AI has demonstrated strong potential in lung cancer detection, with research supporting the need for greater adoption of AI-driven diagnostic tools in clinical settings [20]. AI is not intended to replace clinicians but rather to augment human intelligence, enhancing the speed, accuracy, and reliability of medical

**Table 1.** Example of different applications of AI in oncology.

| Aspect | AI applications in cancer detection | Benefits |
|---|---|---|
| Medical Imaging Analysis | AI-powered image recognition in MRI, CT scans, and mammography | Enhances early tumor detection and reduces missed diagnoses |
| Disease Diagnosis | Machine learning models analyzing pathology slides and biomarkers | Increases diagnostic accuracy and speeds up identification |
| Risk Prediction | AI algorithms assessing genetic, lifestyle, and environmental factors | Identifies high-risk patients for preventive interventions |
| Tumor Classification | Deep learning for precise tumor segmentation and differentiation | Improve accuracy in cancer staging and treatment planning |
| Histopathology | AI-assisted digital pathology for analyzing tissue samples | Reduces human error and enhances efficiency in diagnosis |
| Predictive Analytics | AI-driven models forecasting cancer progression and recurrence | Helps with timely and personalized treatment decisions |
| Personalized Treatment | AI-powered decision support for selecting targeted therapies | Optimizes treatment effectiveness and minimizes side effects |
| Clinical Workflow Automation | AI integration in radiology and oncology workflows | Reduces workload for healthcare professionals and improves efficiency |

This table outlines various aspects of AI application in cancer detection, including medical imaging analysis, tumor classification, and predictive analytics. For each aspect, the corresponding AI technique and its clinical benefit are detailed, showcasing how AI contributes to earlier diagnoses, personalized treatment, and workflow automation in oncology.

diagnoses. As AI technology continues to evolve, its role in cancer detection and personalized treatment strategies will become increasingly vital, revolutionizing the healthcare industry and paving the way for more effective, data-driven medical care.

Furthermore, artificial intelligence (AI) has been investigated for its capacity to accurately diagnose colorectal cancer using histopathology images. This research has shown that AI can deliver prompt and accurate diagnoses [21]. AI technologies have been effectively utilized in healthcare diagnostics to assist in identifying and describing colorectal polyps and other cancerous tissues [22]. In addition, AI has had a substantial impact on the detection of gastric cancer, as evidenced by recent discussions on its implementation [23]. Furthermore, AI has been investigated for its application in diagnosing diabetic nephropathy and prostate cancer, demonstrating its versatility in various types of cancer diagnoses [24,25].

In addition, AI also has been employed in the early identification of pancreatic cancer and kidney cancer [26]. Research has demonstrated the potential of using artificial intelligence (AI) to diagnose gastrointestinal malignancies, particularly those affecting the upper gastrointestinal tract [27]. In addition, AI has been utilized in the timely identification of pharyngeal cancer, showcasing its capability to detect tumors in many parts of the body [28]. Integrating AI into a cancer screening program has demonstrated substantial promise in enhancing detection rates. Research has evaluated the efficacy of AI algorithms in simulated screening scenarios, demonstrating their ability to accurately identify undetected and interval malignancies [29]. In addition, AI has been utilized in extensive screening initiatives like as Breast Screen Norway to examine mammograms and improve the identification of breast cancer instances [30]. Although AI has prospects for improving cancer detection, some problems need to be addressed. One such challenge is the requirement to strike a balance between AI-generated discoveries and conventional diagnostic techniques to provide thorough screening [31]. However, current research is dedicated to broadening the use of AI in the detection and diagnosis of cancer, suggesting a positive outlook for the application of AI in the field of oncology [32].

Furthermore, another research in [33] expanded the usage of AI and advanced deep learning framework to improve the accuracy and efficiency of multiclass skin cancer classification for cancer detection. The methodology integrates an ensemble of two pre-trained convolutional neural networks (CNNs), SqueezeNet and InceptionResNet-V2, to extract diverse and complementary deep features from dermoscopic images. These features are then fused to form a comprehensive feature set, which undergoes optimization through a Modified Whale Optimization Algorithm (MWOA). The MWOA enhances the standard Whale Optimization Algorithm by incorporating a quadratic decay function for dynamic parameter tuning and an advanced mutation mechanism to prevent premature convergence, thereby improving the balance between exploration and exploitation during the optimization process. The optimized features are subsequently classified using machine learning classifiers to achieve robust performance. The framework was evaluated on two benchmark datasets, PH2 and Med-Node, achieving state-of-the-art classification accuracies of 95.48% and 98.59%, respectively. Comparative analyses demonstrated that the proposed method outperformed traditional optimization algorithms such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Slime Mold Algorithm (SMA), as well as existing deep learning-based skin cancer classification models, which have reported accuracies ranging from 87% to 94%. Despite its promising results, the study acknowledges certain challenges, including the reliance on publicly available datasets that may not capture the full variability present in real-world clinical settings, and the increased computational demands due to the ensemble of deep CNNs and the optimization process. The researchers suggest that future work should focus on validating the model across diverse datasets and exploring real-time clinical applications to enhance its generalizability and practical utility.

Moreover, another research in [34] addresses the efficiency of using AI and deep learning framework called CR-Net, designed to enhance the accuracy and efficiency of colorectal cancer (CRC) segmentation in medical imaging. The researchers address the challenges of precise tumor delineation by introducing a semantic network that integrates multi-scale feature extraction and attention mechanisms. CR-Net employs a hierarchical architecture that captures both global context and fine-grained details, facilitating more accurate segmentation of CRC lesions. The methodology involves training the network on annotated datasets, utilizing data augmentation techniques to improve generalization, and implementing loss functions tailored to handle class imbalance inherent in medical imaging data. Key findings demonstrate that CR-Net outperforms existing state-of-the-art methods, achieving higher Dice similarity coefficients and Intersection over Union (IoU) scores on benchmark datasets. The experimental results highlight CR-Net's robustness in handling variations in tumor size, shape, and location, as well as its capability to generalize across different patient populations. However, challenges remain, including the need for large, annotated datasets to train deep learning models effectively, potential overfitting due to limited data diversity, and the computational complexity associated with deploying such models in clinical settings. The study underscores the importance of continued research into optimizing network architectures and training strategies to overcome these limitations and facilitate the integration of advanced segmentation tools into routine clinical practice

Henceforth, the integration of AI, particularly through machine learning (ML) and deep learning (DL), has significantly enhanced cancer diagnosis by improving accuracy, facilitating early detection, and supporting clinical decision-making. AI has demonstrated exceptional diagnostic performance across multiple cancer types, including breast, lung, colorectal, gastric, and skin cancers. With reported accuracy rates exceeding 98% in detecting conditions like metastatic breast cancer and colorectal polyps [19], AI has clearly established its effectiveness. Its ability to identify complex patterns in imaging and histopathology data has contributed to earlier diagnoses and more effective treatment planning, ultimately improving patient survival rates.

A key area of success for AI in oncology is medical imaging. Techniques such as radiomics and deep learning algorithms can identify features in medical scans that are beyond human perception. These applications have enhanced cancer detection capabilities in challenging contexts, such as the segmentation of colorectal tumors using CR-Net or the detection of early gastric cancer through magnified narrow-band imaging. AI has also proven its utility in skin cancer classification, where ensemble models like SqueezeNet and InceptionResNet-V2, combined with optimization algorithms such as the Modified Whale Optimization Algorithm (MWOA) [33], have delivered state-of-the-art performance. These models outperform traditional diagnostic approaches and conventional optimization algorithms, showcasing AI's technical superiority and potential for clinical deployment.

In terms of comparative advantages, AI excels in pattern recognition and high-dimensional data analysis, giving it an edge over traditional diagnostic methods. Its versatility is evident in its application across a broad range of cancers, from gastrointestinal to pharyngeal and pancreatic cancers. Moreover, AI can integrate multimodal datasets, including imaging, genomics, and clinical data, making it a powerful tool for personalized medicine. It also improves operational efficiency by reducing diagnostic errors, accelerating workflows, and easing the burden on healthcare professionals. The incorporation of AI into large-scale screening programs, such as Breast Screen Norway [30], further highlights its scalability and real-world applicability.

However, several limitations temper the current enthusiasm for AI in oncology. A significant concern is the dependency on publicly available datasets that may not reflect the full variability and complexity found in clinical practice. This lack of generalizability poses a risk of overfitting, where models perform well in controlled environments but fail in real-world applications. Furthermore, deep learning models like CR-Net and ensemble CNNs demand substantial computational resources, which may restrict their use in settings with limited technical infrastructure. These models also require large volumes of annotated training data, which are often difficult and costly to obtain.

Clinical validation and regulatory approval represent additional challenges. Many AI models have not yet undergone robust prospective clinical trials, and their integration into routine care remains limited. Concerns around transparency, accountability, and explainability of AI decisions contribute to clinician hesitancy, potentially slowing adoption. Moreover, integrating AI into existing healthcare IT systems and workflows requires significant planning, investment, and training. Resistance from healthcare professionals, due to fears of diminished autonomy or reliance on opaque algorithms, must also be addressed to ensure successful implementation.

Despite these challenges, the clinical impact of AI in cancer diagnostics is significant and growing. AI offers clear advantages in diagnostic precision, speed, and the capacity to process vast and complex datasets. Its ability to augment, rather than replace, human expertise makes it an invaluable tool in modern oncology. To fully realize AI's potential, future research must focus on validating these technologies in diverse clinical settings, improving model interpretability, and ensuring alignment with regulatory standards. In addition, developing scalable, resource-efficient models and promoting multimodal data integration will be key to enhancing generalizability and clinical utility.

In conclusion, AI has revolutionized cancer detection and diagnosis by enhancing accuracy, enabling earlier intervention, and streamlining clinical workflows. While technical and practical limitations remain, ongoing research and development are steadily addressing these issues. With continued advancements, AI is poised to play an increasingly central role in oncology, paving the way for more personalized, data-driven, and effective cancer care.

## 3. AI application for dental and oral healthcare

Dental medicine has greatly benefited from AI, which offers cutting-edge approaches to patient care, diagnosis, treatment planning and dental disorder detection as shown in Table 2. The potential of AI to improve clinical decision-making, treatment outcomes, and dental practice operations is becoming more widely recognized. AI tools, like deep learning models and machine learning algorithms, have been used to analyze radiography pictures, identify oral illnesses, and support treatment suggestions [35]. Both dental practitioners and patients now benefit from more accurate and effective dental diagnostics because of these developments.

Moreover, AI has revolutionized dental education by bringing virtual teaching models and immersive digital tools to improve dental students' learning experiences. By incorporating artificial intelligence (AI) into dentistry education, schools can provide their students with personalized training modules, virtual simulations, and interactive learning environments, which will improve their ability to retain knowledge and build clinical skills [36]. Future dental professionals will be more prepared to use AI technology in their clinical practice thanks to this integration, which also enhances the learning process. AI has had a major impact on dental medicine's ability to diagnose disorders and diseases of the mouth. Artificial intelligence (AI) has been used to develop algorithms that can help diagnose dental cures, periodontal illnesses, and problems of the temporomandibular joint early on. This allows for prompt interventions and individualized treatment programs. Artificial intelligence (AI) systems can detect minute patterns and abnormalities in radiography images and patient data, improving diagnosis precision and treatment results.

AI has also been instrumental in improving the interpretation of dental and maxillofacial radiography pictures, which is important in the field of dental radiology. Dental experts can better accurately diagnose patients and prescribe treatments by using AI algorithms for image segmentation and analysis. This allows them to quickly spot anomalies such as maxillofacial cysts and soft tissue calcification. AI integration in dental radiography leads to faster and more effective patient treatment by streamlining the radio graphic interpretation process and increasing diagnosis accuracy. In the future, artificial intelligence in dentistry has enormous potential to improve patient care, diagnostics, and treatment planning. Dental professionals may expect increasingly complex AI-powered tools and applications that optimize patient experiences, enhance clinical workflows, and improve treatment outcomes as AI technologies advance. In a constantly changing healthcare environment, adopting AI into dentistry practice allows practitioners to use data-driven insights, predictive analytics, and personalized treatment suggestions to provide high-quality, patient-centered care. Significant advancements and promise have been shown in the use of AI in dentistry to support illness prediction, diagnosis, and therapy [37]. Machine learning and artificial neural networks are two examples of AI technologies that are actively used in clinical prediction and therapy, demonstrating their efficacy in enhancing patient outcomes [38]. AI

**Table 2.** Example of different applications of AI in dental healthcare.

| Aspect | AI applications in dental medicine | Benefits |
|---|---|---|
| Patient Care | AI-powered virtual assistants and chatbots for patient inquiries and scheduling | Enhances patient engagement and streamlines appointment management |
| Diagnosis | AI-driven image analysis for detecting dental caries, periodontal disease, and oral cancer | Improves early detection accuracy and reduces diagnostic errors |
| Treatment Planning | AI-based predictive analytics for orthodontic treatment and prosthodontics | Enables personalized treatment plans for better outcomes |
| Dental Disorder Detection | Machine learning models analyzing radiographs and 3D scans to identify anomalies | Speeds up diagnosis and aids in precision-based treatment |
| Oral Cancer Detection | Deep learning algorithms identifying malignant lesions in oral scans | Enhances early detection, leading to timely intervention |
| Endodontics | AI-based assessment of root canal morphology and pathology | Improves precision in root canal procedures and treatment planning |
| Orthodontics | AI-assisted cephalometric analysis and prediction of teeth movement | Enhances treatment efficiency and orthodontic outcomes |
| Prosthodontics | AI-powered CAD/CAM systems for designing dental prosthetics | Ensures accuracy and customization in dental restorations |

The table summarizes the integration of AI in dental medicine across diagnostic, treatment planning, and educational contexts. It presents specific AI functionalities—such as radiograph analysis, orthodontic prediction, and oral cancer detection—alongside the resulting improvements in patient outcomes and clinical efficiency.

has been effectively used in dental and maxillofacial imaging to diagnose dental disorders, classify diseases, and automatically locate anatomical structures with encouraging outcomes [39].

Beyond dentistry, AI has also been heavily incorporated into oral healthcare. The integration of AI in medical diagnostics, particularly in oral healthcare and oral cancer detection, presents a significant advancement toward improving diagnostic accuracy and early detection capabilities. Recent studies illustrate various AI methodologies used for diagnosing oral diseases and lesions, highlighting the considerable potential these technologies possess. AI methodologies, particularly those involving deep learning and machine learning, have demonstrated effectiveness in the early detection of oral cancers. A systematic review indicated the diverse applications of AI in oral cancer diagnosis, emphasizing deep learning networks for analyzing histopathologic images. These methods significantly enhance the identification of premalignant lesions and oral cancers, enabling timely interventions Warin et al. further noted the effective utilization of deep convolutional neural networks to analyze oral lesions, showcasing their capability in early oral cancer detection, with implications for clinical practices [40]. Moreover, AI applications enhance imaging techniques that are fundamental to oral cancer diagnosis. AI has improved the processing of cone beam computed tomography (CBCT) images, facilitating accurate predictions of tumor boundaries. For example, one study demonstrated that AI frameworks could analyze natural images and fluorescence imaging for early signs of oral tumors, achieving superior prediction accuracies compared to traditional methods [41]. The role of AI in image classification is vital for the detection of oral potentially malignant disorders (OPMDs). Research indicates that AI-driven tools can exceed human capabilities in identifying various oral cancers via photographic image analysis, supporting broader screening initiatives, particularly in areas lacking expert clinicians. These findings suggest that AI has the potential to democratize access to oral cancer diagnostics, which can improve outcomes for many patients globally [42]. Machine learning algorithms also enable the development of automated grading systems for oral health conditions. A recent study focused on creating an automatic grading system to assess jawbone mineral density levels using CBCT data, underscoring AI's potential to streamline diagnostic processes and improve the assessment of oral health conditions [41]. Additionally, systematic reviews highlight AI's effectiveness in enhancing the segmentation and detection of oral and maxillofacial structures, providing valuable contributions to fields including orthodontics and surgery [43]. The ongoing evolution of AI technologies promises to refine diagnostic and follow-up processes in oral healthcare. Models predicting postoperative recurrence in oral cancer indicate potential for enhancing long-term patient management, underscoring AI's crucial role in prognostication [44]. Furthermore, integrating advanced imaging modalities with AI not only improves diagnostic accuracy but also aids clinical decision-making strategies [45].

Thus, AI has demonstrated considerable effectiveness in transforming dental medicine by enhancing diagnostic accuracy, streamlining treatment planning, and optimizing patient care. Its integration into diagnostic tools, such as radiographic analysis and disease detection systems, has significantly improved clinicians' ability to identify oral diseases, periodontal issues, and temporomandibular joint disorders. Deep learning models and machine learning algorithms have enabled more precise interpretations of dental radiographs, assisting in the detection of subtle anomalies like maxillofacial cysts and soft tissue calcifications. This precision facilitates earlier intervention and more personalized treatment plans, ultimately contributing to improved patient outcomes.

A key comparative advantage of AI lies in its ability to process and interpret large volumes of complex imaging and clinical data with high consistency and speed, outperforming traditional diagnostic methods in several scenarios. AI applications have also expanded to dental education, where virtual teaching models and personalized learning environments have enhanced student engagement and skill acquisition. The use of AI-driven simulations enables dental students to gain clinical experience in a controlled setting, promoting better preparedness for real-world practice. Furthermore, in oral healthcare, AI has proven effective in early oral cancer detection. Deep learning networks have shown particular promise in analyzing histopathological and photographic images, significantly aiding in the identification of premalignant lesions and oral cancers. These innovations not only improve diagnostic capabilities but also broaden access to screening in underserved regions by reducing reliance on specialized clinicians.

Despite its many advantages, the implementation of AI in dental and oral healthcare is not without limitations. One major concern is the reliance on high-quality, annotated datasets to train AI models, which may not be representative of all patient populations or clinical scenarios. This limitation raises the risk of bias and reduces the generalizability of AI systems in diverse settings. Additionally, while AI excels in detecting patterns, it lacks contextual understanding and clinical reasoning, which are crucial in complex cases that require nuanced decision-making. Another challenge is the computational demand of advanced models, which may hinder widespread adoption in resource-limited environments. Furthermore, the integration of AI into existing clinical workflows and regulatory frameworks remains a work in progress, with issues surrounding data privacy, algorithm transparency, and practitioner trust needing to be addressed.

Nonetheless, the clinical impact of AI in dentistry is already evident. From improving diagnostic precision and accelerating radiographic interpretation to enhancing prognostication and treatment planning, AI is reshaping the landscape of oral health care. For instance, AI-driven tools have been employed in automatic grading systems for jawbone density assessment [41] and segmentation of oral structures, contributing significantly to orthodontics and maxillofacial surgery [39]. The ability of AI to support early detection of oral cancers through fluorescence imaging and cone beam computed tomography (CBCT) analysis is particularly promising, offering new pathways for timely and effective interventions. These advancements suggest a paradigm shift toward data-driven, personalized care models in dentistry.

In conclusion, AI presents a transformative opportunity in dental and oral healthcare, offering substantial improvements in diagnostics, education, and clinical decision-making. While current limitations—such as data diversity, computational requirements, and integration challenges must be addressed through continued research and development, the trajectory of AI adoption remains positive. With its potential to democratize access, increase diagnostic efficiency, and improve outcomes, AI is poised to become an integral part of modern dental practice and oral health management.

## 4. AI application for brain tumor database management

AI has greatly enhanced brain tumor research by creating brain tumor databases. Artificial intelligence (AI) technologies, such as machine learning and deep learning algorithms, have enabled the development of extensive databases that store and analyze large quantities of brain imaging data. These databases are used to enhance diagnosis, treatment planning, and research in the field as shown in Table 3. These databases are essential for making decisions based on data, improving clinical results, and furthering our knowledge of brain tumors. AI-driven content-based image retrieval systems have played a crucial role in detecting brain tumors in extensive medical picture collections. Using AI algorithms, these systems effectively analyze MRI brain scans, extract pertinent aspects, and obtain images that indicate the presence of brain cancers. This method simplifies the process of identifying brain tumors and helps accurately classify and characterize them [46].

AI has been employed to evaluate the likelihood of ischemic stroke in adult individuals who have previously had brain tumors, specifically in the setting of brain cancer survivors. Research has demonstrated that people who have malignant primary brain tumors are at a greater risk of experiencing ischemic stroke, which results in more unfavorable outcomes compared to individuals who do not have brain tumors. AI-powered risk

**Table 3.** Example of different applications of AI in brain tumor databases creation.

| Aspect | AI applications in brain tumor databases creation | Benefits |
|---|---|---|
| Diagnosis | AI-driven analysis of MRI and CT scans for tumor detection | Improves accuracy and enables early detection |
| Tumor Classification | Deep learning models categorizing tumor types (e.g., benign vs. malignant) | Enhance precision in diagnosis and treatment selection |
| Treatment Planning | AI-assisted predictive models for personalized treatment strategies | Optimizes therapy choices and improves patient outcomes |
| Risk Assessment | Machine learning algorithms analyzing genetic and clinical data | Identifies high-risk patients and supports preventive care |
| Tumor Segmentation | AI-powered image segmentation techniques | Improves precision in defining tumor boundaries for surgery |
| Medical Imaging Analysis | Automated AI analysis of radiological data for tumor progression tracking | Aids in monitoring treatment effectiveness and disease progression |
| Research & Drug Development | AI-driven insights from large-scale brain tumor datasets | Accelerates discovery of new therapies and treatment protocols |
| Clinical Decision Support | AI integration into electronic health records and diagnostic tools | Assists doctors in making data-driven, informed decisions |

This table details AI-enabled approaches in the development and utilization of brain tumor databases. It includes applications like tumor classification, segmentation, treatment planning, and clinical decision support, highlighting their benefits in improving diagnostic accuracy, risk assessment, and therapeutic outcomes.

assessment models provide useful insights to inform clinical practice and improve stroke risk management in individuals who have survived brain tumors [47]. AI is essential in optimizing corticosteroid therapy for brain tumor patients who have adrenal insufficiency. AI algorithms aid healthcare providers in establishing the optimal dosage, timing, and duration of corticosteroid therapy for brain tumor patients, considering unique patient features and treatment responses. This individualized strategy improves the effectiveness of treatment and reduces the likelihood of adverse consequences [48].

Furthermore, adrenal insufficiency is evaluated using artificial AI in children with brain tumors who are receiving hematopoietic cell transplantation (HCT) which requires careful monitoring and treatment. AI technologies assist in the early identification of adrenal insufficiency, allowing for prompt therapies and enhanced patient outcomes. Furthermore, explainable AI systems have been created to improve the interaction between humans and machines in the process of localizing brain tumors. By integrating interoperability elements into AI algorithms, physicians can gain a deeper understanding of how AI models make decisions when detecting and characterizing brain cancer lesions [49]. This level of openness enhances confidence in AI-driven diagnoses and allows physicians to verify and improve diagnostic outcomes, ultimately boosts the precision and dependability of brain tumor localization.

Using publicly available datasets, several researchers have used deep learning models, like conventional neural networks, to categorize various forms of brain cancers [50]. Furthermore, novel methods for classifying brain tumors from MRI images have been investigated, such as swarm optimization in conjunction with neural networks [51]. Furthermore, the integration of AI technologies has proven to be crucial in enhancing the precision of image retrieval systems utilized for brain tumor analysis. This has enabled the swift and effective extraction of pertinent brain tumor images from extensive databases [52,53]. Moreover, segmenting tumors from MRI images using AI is another way that brain tumor research is using AI [54]. Singular value decomposition and dual autoencoder are two techniques that have been developed for maximizing features in brain tumor segmentation, demonstrating the variety of approaches used in this field [54]. Furthermore, databases such as ReMIND and RESECT offer useful clinical information to validate image registration algorithms and improve the accuracy of brain tumor resection techniques [55,56].

Hence, the integration of AI into brain tumor research has significantly improved data management, diagnostic accuracy, treatment personalization, and research capabilities. One of the most notable contributions is the creation of AI-enhanced brain tumor databases, which consolidate and analyze vast amounts of brain imaging data, primarily MRI scans. These databases support data-driven decision-making in both clinical and research settings, facilitating early and accurate tumor detection, patient-specific treatment planning, and improved outcomes. AI-powered content-based image retrieval systems efficiently classify tumor types and aid radiologists by providing visual matches based on historical data, enhancing diagnostic precision.

AI has also proven effective in secondary risk prediction, such as assessing ischemic stroke risk in brain cancer survivors. AI-driven models help stratify patients based on risk, enabling proactive care strategies. Similarly, AI applications in optimizing corticosteroid therapy and managing adrenal insufficiency in brain tumor patients illustrate the role of AI in personalizing treatments, ensuring better therapeutic outcomes and reducing side effects. Moreover, the use of explainable AI enhances trust by making the decision-making process transparent for clinicians, improving user confidence and supporting human-AI collaboration in diagnostic tasks.

Compared to traditional diagnostic and treatment planning tools, AI brings significant advantages. AI systems can analyze and learn from massive imaging datasets far faster and more accurately than human clinicians. This not only reduces diagnostic workload but also standardizes interpretation, minimizing human error and inter-observer variability. The ability of AI algorithms to perform tumor segmentation, classification, and image retrieval in near-real time represents a leap forward in clinical efficiency and precision. Furthermore, novel AI methodologies—such as combining swarm optimization with neural networks—show improved performance over conventional algorithms in classifying and segmenting brain tumors. Publicly available datasets such as ReMIND and RESECT, used to validate and train AI models, further strengthen research reproducibility and clinical translation. AI also aids in surgical planning through enhanced image registration, improving the precision of tumor resections. Such innovations directly support more effective and less invasive treatments.

Despite these promising outcomes, there are several limitations. First, the generalizability of AI models is constrained by the quality and diversity of training datasets. Many models are developed using publicly available datasets that may not adequately represent the full clinical spectrum, potentially leading to biased or less robust models in real-world settings. There are also concerns regarding overfitting in deep learning models, particularly when data is limited or not well-annotated. Second, the computational intensity of AI models, especially deep learning networks, poses practical barriers to implementation in low-resource or time-sensitive clinical environments. Additionally, while explainable AI is a growing field, many AI systems remain "black boxes," with decision-making processes that are difficult to interpret, potentially limiting clinical adoption. Another limitation is the need for regulatory oversight, ethical considerations around data privacy, and standardization of AI tools before they can be fully integrated into clinical workflows. Integration challenges also persist, including interoperability with existing hospital systems and the need for clinician training on AI systems.

In addition, the clinical impact of AI in brain tumor management is substantial. From assisting in accurate and early detection to informing post-treatment risk assessments and optimizing therapeutic regimens, AI has the potential to revolutionize care delivery. The ability to tailor treatments, identify patients at high risk of complications, and facilitate more accurate surgeries has meaningful implications for survival rates and quality of life. AI systems also alleviate clinician burden, allowing medical professionals to focus more on patient interaction and less on time-consuming image analysis.

Moreover, the advancement of AI in brain tumor localization and classification supports better-informed decisions, reducing diagnostic uncertainty and improving surgical planning. Ultimately, this leads to faster diagnoses, more effective treatments, and better patient outcomes. As AI technologies evolve, their integration into brain tumor research and clinical practice promises to reshape the field of neuro-oncology with smarter, data-driven approaches.

In conclusion, the application of AI in brain tumor research demonstrates strong effectiveness in improving diagnosis, treatment personalization, and data management. While there are notable limitations related to generalizability, computational requirements, and integration barriers, the comparative advantages of AI such as enhanced diagnostic precision, data retrieval, and workflow optimization are compelling. The clinical impact is already visible in better treatment planning and patient monitoring, with ongoing advancements likely to deepen AI's role in neuro-oncology. Continued research, ethical oversight, and clinical validation will be essential to unlocking its full potential.

## 5. AI application for personalized medical treatment planning

The concept of personalized treatment planning in the framework of AI applications in medical diagnosis is fast advancing and has great potential for enhancing patient outcomes and bringing countless benefits as shown in Table 4. AI technology, such as machine learning algorithms, is being more and more used to customize treatment programs for individual patients, considering their distinct traits and medical history. Multiple

Table 4. Example of different applications of AI in personalized medical treatment planning.

| Aspect | AI applications in personalized medical treatment planning | Benefits |
|---|---|---|
| Patient Data Analysis | AI-driven algorithms analyzing medical history, genetics, and biomarkers | Enables data-driven, customized treatment plans |
| Disease Diagnosis | Machine learning models identifying disease patterns and severity | Enhances diagnostic accuracy for targeted treatments |
| Treatment Optimization | AI-powered decision support for selecting the best therapy options | Reduce trial-and-error approaches, improving patient outcomes |
| Predictive Analytics | AI forecasting disease progression and treatment response | Helps in proactive and adaptive treatment planning |
| Drug Response Prediction | AI-driven analysis of patient-specific drug interactions and effectiveness | Personalizes medication selection, minimizing adverse effects |
| Radiotherapy Planning | AI-assisted precision radiation dose calculation and adaptive therapy | Reduces damage to healthy tissues while improving efficiency |
| Surgical Planning | AI-powered imaging and robotic-assisted surgery guidance | Enhance precision, safety, and recovery rates |
| Remote Monitoring | AI-based wearable devices and telemedicine for real-time health tracking | Allow continuous monitoring and treatment adjustments |
| Genomic Medicine | AI-driven insights into genetic mutations for targeted therapies | Advances precision medicine for complex diseases |
| Clinical Decision Support | AI integration in healthcare systems for personalized treatment recommendations | Assists doctors with real-time, evidence-based decision-making |

The table explores how AI supports the customization of medical treatment strategies by analyzing diverse patient data. It includes use cases in radiotherapy, surgery, remote monitoring, and genomic medicine, emphasizing AI's role in enhancing treatment precision and patient care.

studies have emphasized the significance of artificial intelligence (AI) in improving treatment planning in different medical fields. Wang examined the application of deep learning algorithms in radiotherapy treatment planning, highlighting the progress and potential future developments in this field [57]. In a similar vein, Hussein highlighted the significance of artificial intelligence (AI) in discerning individualized treatment strategies for patients undergoing radiotherapy. This technology assists in making personalized decisions at an individual level [58].

In addition, AI has demonstrated potential in the field of dentistry, as emphasized by Schwendicke. AI-powered solutions are now being employed for purposes such as dental diagnostics, treatment planning, and record-keeping. This illustrates the wide-ranging uses of artificial intelligence (AI) in healthcare that go beyond the conventional medical domains [59]. AI has played a crucial role in the field of oncology by aiding in screening, diagnosis, selection of treatment, and prediction of prognosis for illnesses such as colorectal cancer [60]. AI's capacity to analyze extensive clinical and omics data empowers clinicians to identify patients at high risk and suggest precise and personalized treatment approaches. In addition, the incorporation of artificial intelligence (AI) in medical imaging, specifically cone-beam computed tomography (CBCT) for online adaptive radiotherapy, as explained by Sibolt demonstrates how AI may automate the identification of organs and improve the process of treatment planning [61]. By adopting a personalized strategy, there is a considerable opportunity to greatly improve patient outcomes and minimize the likelihood of negative reactions to medication [62]. Progress from standardized treatment procedures to individualized medicine has been expedited by developments in data science and artificial intelligence [63]. These technologies facilitate the creation of treatment strategies that are highly accurate and efficient, ultimately resulting in enhanced patient results and decreased healthcare expenses [64]. Healthcare experts are progressively acknowledging the significance of using artificial intelligence (AI) in personalized medicine to provide efficient and top-notch care [65]. The incorporation of artificial intelligence (AI) in the field of pathology has simplified diagnostic processes and enhanced the precision of illness identification.

Molecular imaging is essential in customizing treatment for individual patients in the field of personalized medicine [66]. Through the utilization of artificial intelligence (AI) in medical imaging, namely in radionics and deep learning applications, medical professionals can derive significant and meaningful information from imaging data. This information can then be used to guide personalized treatment strategies for illnesses such as pancreatic cancer [67]. AI is becoming more prevalent in other medical fields, such as dermatology and urinary disorders. Healthcare practitioners are increasingly using AI-powered technologies for personalized treatment planning and diagnostic imaging [68,69]. Furthermore, the utilization of artificial intelligence (AI) in disease diagnosis has brought about a significant transformation in the healthcare industry. It has accelerated the delivery of patient care and improved the efficiency of treatment planning procedures [70]. The application of artificial intelligence (AI) in medical imaging not only improves the process of planning therapy but also enables doctors to make well-informed decisions by analyzing extensive data [71]. AI is being used more and more in many medical specializations. AI and radiomics work together to predict patient outcomes in oncology, which opens the door to tailored treatment [72]. Artificial neural networks are used in dentistry to diagnose issues such as dental cavities and impacted teeth, demonstrating the wide range of healthcare applications of AI [73]. With a focus on individualized medicine for improved patient care, the use of AI in obstetrics and gynecology is becoming more and more prominent [74]. Furthermore, AI is being investigated for the treatment of renal illness, which is advancing medical practice toward AI-directed medicine and intelligent diagnostics [75]. Notwithstanding AI's promise for medical diagnostics, issues including customer resistance and data bias need to be resolved. Diagnostic accuracy may be impacted by biased AI classifiers resulting from gender imbalance in medical imaging datasets [76]. The necessity to address psychological issues in adoption in AI is highlighted by the possibility that consumer resistance to AI suggestions in medical contexts is due to beliefs about the technology's reliability [77].

Besides that, AI is also implemented in Covid-19 detection in personalized treatment for patients. In the research in [78], various methodologies are employed to enhance the detection of COVID-19 through advanced imaging techniques, notably chest radiography and CT scans, which offer advantages such as rapidity and cost-effectiveness compared to traditional rRT-PCR tests. The study specifically investigates the application of Convolutional Neural Networks (CNNs) within medical imaging, a method that has garnered significant interest due to its ability to analyze complex datasets and accurately classify images for diagnostic purposes. One of the key findings highlights the efficacy of different deep learning architectures in improving diagnostic accuracy. The authors conducted experiments evaluating various CNN models and their performance in distinguishing COVID-19 infections from other lung diseases, demonstrating that optimized model selection can yield higher sensitivity and specificity rates. Their methodology involved a systematic approach to model training, validation, and testing across diverse datasets, which supports the robustness of their findings. Furthermore, the study emphasizes the importance of information fusion techniques that combine multiple imaging modalities to enhance overall diagnostic performance. However, the researchers also acknowledge several challenges faced during the implementation of these deep learning methods. The biggest among them is the reliance on high-quality, annotated datasets, which are crucial for the training and evaluation of CNN models. The scarcity of such datasets, particularly in real-world clinical settings, poses significant hurdles. Additionally, the discussion includes the computational intensity required for training deep learning models, necessitating substantial hardware resources and expertise. Overall, the research represents a significant advancement in the use of artificial intelligence for medical diagnostics, emphasizing both the potential and challenges in leveraging such technologies for enhanced clinical practice.

In addition, AI technology is also used in cardiovascular risk prediction during personalized treatment to provide a better analysis of cardiovascular health for patents. In the study by Zaidi et al. in [79], the researchers propose a novel framework for predicting cardiovascular disease (CVD) risk, reflecting the urgent necessity for accurate risk assessment methodologies in light of CVD's significant global mortality impact. The investigation employs a hybrid ensemble learning approach that integrates multiple machine learning algorithms to enhance predictive accuracy. Specifically, the methodology entails a comprehensive analysis of various data preprocessing techniques and model selection processes, as well as the implementation of an innovative framework called HeartEnsembleNet, which synergizes the strengths of individual models to produce a robust predictive outcome Key findings from the research reveal that the ensemble model substantially outperforms individual machine learning algorithms in predicting CVD risk, achieving notable improvements in sensitivity, specificity, and overall accuracy. The framework was rigorously tested using a well-curated dataset representing diverse patient demographics, thus establishing its generalizability and effectiveness across a broader population. Additionally, the use of ensemble techniques enables the model to mitigate potential biases inherent in single algorithms, improving reliability in clinical applications. Nonetheless, the study acknowledges several challenges associated with implementing such innovative techniques. One major concern involves the complexity associated with ensemble methods, as they require intricate handling of multiple models, which may pose interpretative difficulties for healthcare professionals seeking to understand the underlying decision-making processes. Furthermore, the authors highlight the necessity of extensive, high-quality datasets for training and validation, as real-world clinical data can often be incomplete or lack uniformity, potentially hindering the model's predictive capabilities. The research represents a meaningful advancement in CVD risk prediction, illustrating both the potential of ensemble learning in healthcare and the ongoing challenges faced by practitioners in integrating these sophisticated models into clinical environments.

Hence, AI plays an increasingly central role in advancing personalized treatment planning across various medical specialties. The integration of machine learning (ML) and deep learning (DL) algorithms has significantly enhanced the ability to customize treatment strategies based on individual patient characteristics, clinical data, and medical history. The reviewed section comprehensively illustrates the breadth of AI applications in treatment personalization, including domains such as oncology, radiotherapy, dentistry, cardiovascular medicine, nephrology, and infectious diseases like COVID-19. AI driven tools enable the analysis of large-scale clinical and omics datasets, allowing clinicians to stratify patients based on risk and tailor interventions accordingly. For instance, in oncology, the use of radiomics and DL facilitates the automated identification of tumor features that are instrumental in guiding individualized treatment paths. Similarly, in cardiovascular care, ensemble learning approaches like HeartEnsembleNet [79] demonstrate superior performance in risk prediction by integrating multiple models for enhanced diagnostic accuracy.

The comparative advantages of AI over traditional treatment planning methods are well-articulated. AI systems can integrate diverse data types, ranging from imaging to electronic health records—and process them rapidly to support clinical decision-making. The automation of imaging tasks, such as organ segmentation in adaptive radiotherapy using cone-beam computed tomography (CBCT), exemplifies the efficiency gains achievable with AI. Moreover, AI's predictive capabilities allow for early disease detection and preemptive interventions, which are critical for improving outcomes and reducing healthcare costs. The wide applicability of AI in various fields—from dermatology and obstetrics to dentistry and nephrology, further illustrates its scalability and utility across the healthcare spectrum.

However, the section also implicitly and explicitly highlights several limitations that must be addressed for AI to be fully integrated into clinical workflows. A major concern is the dependency on high-quality, annotated datasets for training AI models. Bias in these datasets such as gender or racial imbalances can lead to skewed outcomes and reduce the reliability and fairness of AI systems. Additionally, many AI models, especially deep neural networks and ensemble methods, function as "black boxes," offering limited interpretability. This lack of transparency hinders clinician trust and impairs the ability to validate AI-generated recommendations. The section also acknowledges infrastructural and expertise-related barriers, as implementing and maintaining AI systems require substantial computational resources and technical knowledge, which may not be readily available in low-resource settings.

Another critical challenge discussed is the psychological resistance to AI adoption among both patients and healthcare professionals. Concerns about the reliability of AI-generated decisions, compounded by the perceived loss of human oversight, can lead to reluctance in integrating AI tools into practice. Furthermore, while not extensively covered in the section, the ethical and regulatory dimensions of AI use in personalized medicine remain an important consideration. Issues surrounding data privacy, informed consent, and accountability of AI decisions need to be resolved to ensure safe and equitable implementation.

Clinically, the impact of AI in personalized treatment planning is both significant and transformative. AI facilitates more accurate diagnoses, improves treatment efficacy, and supports preventive care strategies by identifying at-risk individuals before the onset of symptoms. In radiotherapy and oncology, AI tools optimize dosing and targeting strategies, minimizing side effects and improving patient outcomes. AI-based diagnostic systems also expand access to specialist-level care in underserved regions by providing decision support to non-expert practitioners. Additionally, AI enables better resource allocation by streamlining workflows and reducing unnecessary diagnostic procedures.

In conclusion, the reviewed section offers a comprehensive and insightful overview of AI's transformative potential in personalized treatment planning. The effectiveness of AI in enhancing diagnostic precision, treatment customization, and workflow optimization is clearly proven. However, realizing the full clinical potential of these technologies requires overcoming substantial challenges related to data quality, model transparency, infrastructure, and trust. Future research and implementation strategies must prioritize the development of explainable, unbiased, and user-friendly AI systems to ensure their safe and equitable integration into routine medical practice. By addressing these challenges, AI can truly fulfill its promise of revolutionizing personalized medicine and improving patient care across diverse clinical settings.

## 6. Challenges

While artificial intelligence (AI) has shown considerable promise in revolutionizing cancer diagnostics—particularly in areas such as brain tumor detection, personalized treatment planning, and oral cancer diagnosis—it faces a range of technical, clinical, ethical, and infrastructural challenges that limit its efficacy and adoption in routine clinical practice. Addressing these challenges is crucial to fully harnessing the transformative potential of AI in oncology and broader medical domains.

One of the most significant technical challenges lies in the domain of brain tumor detection, where AI has demonstrated both promise and pitfalls. Despite progress in using deep learning algorithms to classify tumors from MRI scans, the variability and heterogeneity of tumor types remain major obstacles. Brain tumors often exhibit complex, irregular morphologies and overlapping imaging features, which challenged consistent recognition by AI models. Han noted that even minor differences in tumor shape or contrast enhancement can significantly affect model performance, leading to diagnostic inaccuracies [80,81]. Furthermore, many AI algorithms are trained on small, homogenous datasets derived from single-institution cohort, limiting their ability to generalize across diverse patient populations and imaging equipment. This lack of generalizability often results in poor reproducibility in real-world clinical settings. As Musa et al. emphasize, without large, multi-center datasets that represent variations in demographics, disease presentation, and imaging protocols, the reliability of AI tools remains in question [82]. A promising solution to this issue lies in federated learning, a method that enables AI models to be trained collaboratively on decentralized data from multiple institutions without compromising patient privacy. This approach could significantly enhance generalizability while respecting ethical constraints.

In addition to technical constraints, AI applications in personalized treatment planning encounter challenges in balancing algorithmic complexity with clinical relevance. Although AI can process large volumes of historical treatment data to suggest optimal therapies, it often fails to adequately incorporate nuanced individual characteristics such as genetic predisposition, lifestyle factors, or comorbidities. As a result, the recommendations made by AI systems may be more reflective of population trends than genuinely personalized medicine. Zheng et al. argue that transitioning from diagnostic analytics to predictive and prescriptive analytics will require AI systems to integrate multiple modalities of patient data—ranging from genomic and proteomic profiles to longitudinal health records through more sophisticated, multi-layered algorithms [83].

The development of hybrid models combining rule-based systems with machine learning may help address this by embedding clinical guidelines and expert knowledge into AI decision-making frameworks. However, these improvements also raise serious ethical concerns. The aggregation and processing of sensitive health data pose risks related to patient privacy, consent, and data misuse. Regulatory bodies and healthcare institutions must implement strict data governance frameworks and transparent consent protocols to mitigate these risks. Moreover, explainability in AI, making model decisions interpretable to clinicians and patients alike will be vital in ensuring trust and accountability in personalized treatment planning.

In dental healthcare, AI holds great potential for early detection of oral cancers, but its deployment faces unique contextual challenges. Veeraraghavan et al. notes that most AI systems in this domain are developed using high-resolution imaging data obtained in tertiary care or academic settings [84]. As a result, these models often underperform when applied in general dental clinics where imaging quality and clinical protocols vary widely. This discrepancy in performance presents a barrier to widespread implementation, particularly in resource-limited settings. Moreover, the diversity in practitioner expertise introduces another layer of variability. While some dental professionals may embrace AI-assisted diagnostics, others may distrust these tools due to perceived threats to clinical autonomy or concerns over liability. Integrating AI into everyday dental workflows therefore requires not only technological adjustments but also targeted education and training initiatives. Continuing professional development programs focused on the use of AI in dental diagnostics could bridge the gap between technological innovation and clinical acceptance. Additionally, developing AI interfaces that are user-friendly and compatible with existing dental practice management software can facilitate smoother integration into routine care without disrupting established workflows. Furthermore, integrating AI tools into routine dental practice requires substantial training and adaptation from practitioners, as the willingness to trust AI recommendations can vary significantly among professionals. The need for AI systems to work alongside existing clinical workflows without disrupting them poses an additional barrier to widespread adoption.

The challenge of clinician trust is not limited to dentistry. Across medical fields, skepticism toward AI-generated recommendations remains a significant barrier. Studies have shown that clinicians are more likely to accept AI assistance when they can understand the rationale behind its outputs. This underscores the importance of explainable AI (XAI), which allows users to trace how a model arrived at a particular decision. For example, heatmaps in imaging-based diagnostics can highlight regions of interest that influenced the model's classification, helping clinicians verify findings. Tools such as SHAP (Shapley Additive Explanations) or LIME (Local Interpretable Model-agnostic Explanations) can also be integrated into clinical AI systems to provide insight into tabular or structured data decisions. Making AI transparent and interpretable not only boosts user confidence but also facilitates regulatory compliance and clinical auditing.

Another key limitation is the lack of comprehensive, high-quality annotated datasets. Whether in cancer imaging, genomic profiling, or treatment response prediction, AI performance is highly dependent on the quality of its training data. Annotating such data often requires expert input, which is both time-consuming and expensive. The scarcity is further exacerbated in rare cancers or minority populations, leading to biases that can perpetuate health disparities. To address this, collaborative data-sharing initiatives, such as The Cancer Imaging Archive (TCIA) or the UK Biobank, have emerged to pool resources across institutions. However, broader participation and standardized data formats are essential to maximize the utility of these datasets. Governments and funding agencies must incentivize open science and data-sharing practices while safeguarding patient privacy through anonymization and secure data infrastructures.

Despite these challenges, the potential for AI to revolutionize cancer diagnostics and treatment remains significant. The ability of AI to detect subtle imaging abnormalities, stratify patient risk, and recommend treatment plans based on vast datasets promises improved outcomes and more efficient healthcare delivery.

However, as this review highlights, realizing this potential requires a multi-pronged strategy: advancing technical robustness through multi-institutional training, promoting ethical AI use via transparent consent and explainability, enabling clinician adoption through targeted training, and addressing infrastructural gaps through investment in interoperable systems. Tackling these challenges holistically will be critical to integrating AI seamlessly and safely into the future of oncology and personalized medicine. Table 5 summarizes the discussion of various challenges presented in this section.

In conclusion, while AI has the potential to revolutionize cancer diagnosis and treatment, various challenges must be systematically addressed, including generalizability issues, data diversity, and practitioner engagement in areas like brain tumors, dental healthcare, and personalized treatment planning. With continuous research and development, the limitations of AI can be mitigated, paving the way for more effective and trustworthy clinical applications.

## 7. Prospects

The integration of artificial intelligence (AI) into medical diagnostics offers transformative potential across domains such as oncology, neurology, and dental healthcare. As AI systems continue to evolve, so too does their capacity to enhance diagnostic accuracy, streamline clinical workflows, and personalize treatment strategies. However, realizing this potential requires more than technological advancement alone. It demands a strategic, multidisciplinary approach that includes improvements in data integration, algorithm development, clinical education, ethical safeguards, and standardized validation frameworks. This section explores the key prospects for AI in medical diagnostics and proposes a cohesive vision for its future development and implementation.

A central pillar for advancing AI in cancer diagnostics lies in the seamless integration of heterogeneous data types. AI systems must evolve from single-modality models, such as those reliant solely on imaging, to multi-modal platforms that synthesize imaging data, genomic profiles, electronic health records, pathology reports, and longitudinal clinical histories. This integration is crucial for capturing the complexity of individual patient profiles and generating accurate, context-aware diagnostic and prognostic outputs. Jan et al. [85] demonstrated how AI systems that integrate diverse datasets—such as radiomic and genomic data—can enhance early cancer detection, particularly for elusive malignancies like pancreatic cancer, which often present late and with nonspecific symptoms. These platforms can identify subtle patterns invisible to the human eye, offering predictive insights that go beyond traditional diagnostic capabilities. Moreover, when designed to support real-time feedback loops, AI systems can continuously learn and improve with incoming data, increasing adaptability in dynamic clinical settings [86]. Future research must prioritize the development of scalable, interoperable architectures capable of facilitating this type of continuous, data-driven learning across institutional and geographic boundaries.

In the realm of oral healthcare, AI's potential remains underutilized but promising. As oral cancer continues to pose diagnostic challenges due to its heterogeneous presentation and reliance on subjective clinical

Table 5. Challenges of AI applications in medical diagnosis.

| Area of application | Challenges | Potential of AI |
|---|---|---|
| Brain Tumor Detection | Variability and complexity of tumor presentations<br>- Issues with generalizability and reproducibility<br>- Limited training datasets<br>- Integration of heterogeneous | - Potential for early detection of brain tumors<br>- Deep learning for complex imaging analysis<br>- Multi-modal learning techniques |
| Personalized Treatment | - Lack of individualized patient data consideration<br>- Current systems often provide generalized recommendations<br>- Ethical concerns about data privacy & consent | - AI can recommend treatment based on historical outcomes<br>- Future shift to predictive analytics for truly personalized treatments |
| Dental Healthcare | - Variability in clinical environments<br>- AI systems reliant on high-quality training data from specialized clinics<br>- Practitioner adaptation and trust in AI tools | - Potential to assist in diagnosing oral cancers<br>- Early detection through quick imaging analysis<br>- Stratifying patient risk |
| General AI Applications | - Need for robust validation processes<br>- Data diversity and representation across populations<br>- Integration into existing clinical workflows | - Early detection of cancer<br>- Better stratification of patient risk<br>- Personalized intervention strategies |

This table presents key challenges encountered in applying AI to medical diagnostics. It categorizes the challenges by domain (e.g., brain tumor detection, dental healthcare), describes the limitations, and contrasts them with the corresponding potential of AI in each area.

examination, AI tools could support early detection through automated image analysis and risk prediction. However, widespread adoption in dental practice hinges on the validation of these tools within diverse clinical settings. Veeraraghavan et al. [84] emphasizes the necessity of rigorous, multi-center trials and systematic reviews to assess AI's effectiveness across varying practice environments. Furthermore, co-development of AI tools with input from dental professionals can ensure that systems align with real-world workflows, enhancing usability and clinician trust. This participatory approach could be facilitated through pilot programs in academic dental institutions, where iterative feedback can refine tool functionality prior to broader implementation. Collaborative design not only improves clinical relevance but also fosters a culture of shared responsibility in AI adoption.

Education represents another vital frontier in preparing healthcare professionals to work effectively alongside AI. As Halat et al. [86] have shown, dental students and medical trainees are increasingly interested in understanding AI technologies, yet many curricula lack dedicated content on this subject. Incorporating AI literacy into medical and dental education—through interdisciplinary courses that cover both technical and ethical dimensions—will be essential for equipping future clinicians with the skills to interpret, validate, and apply AI-generated insights responsibly. Curricula should also include training on bias recognition, algorithmic transparency, and troubleshooting of AI tools. Simulation-based modules could be especially beneficial, allowing students to practice using AI in diagnostic scenarios and reflect on decision-making processes. These educational efforts must be extended to current practitioners through continuing education and certification programs to ensure AI literacy across the professional spectrum.

Ethical considerations will continue to shape the trajectory of AI in diagnostics. As AI systems assume more decision-making responsibility, questions about data privacy, consent, liability, and accountability become increasingly salient. Zhang et al. [87] call for transparent frameworks that govern AI deployment, particularly in high-stakes fields like oncology. To this end, policymakers and healthcare institutions must establish ethical guidelines that address issues such as the secondary use of data, algorithmic bias, and the explainability of model decisions. Regulatory bodies should mandate the use of explainable AI (XAI) methodologies in clinical AI systems to ensure that outputs are interpretable not only by data scientists but also by clinicians and patients. For example, heatmaps in radiology or decision-trees in treatment recommendations can help trace the rationale behind AI predictions, thereby fostering trust and reducing the risk of over-reliance on opaque algorithms. Additionally, embedding ethical impact assessments into AI development pipelines like environmental impact assessments could serve as a proactive safeguard.

Standardization and validation of AI tools represent foundational steps for ensuring safety, efficacy, and clinical utility. As it stands, the lack of standardized protocols for evaluating AI systems creates uncertainty around their readiness for deployment. Comprehensive validation frameworks should include diverse datasets reflective of real-world variability, robust performance metrics (such as sensitivity, specificity, and area under the curve), and stress-testing under uncommon or borderline cases. These standards must be enforced by regulatory agencies such as the FDA, EMA, or equivalent regional bodies to promote transparency and accountability in the AI marketplace. Additionally, centralized repositories for benchmarking AI diagnostic tools similar to ImageNet for computer vision could enable consistent comparison and continual improvement.

Moreover, the possible prospect of applying TRIZ (Theory of Inventive Problem Solving) can be a valuable framework for enhancing AI applications in medical diagnosis by providing systematic methods to identify and overcome challenges [88,89]. By identifying contradictions, such as balancing diagnostic accuracy with speed, TRIZ helps pinpoint areas for improvement [90,91]. Utilizing inventive principles, AI algorithms can be designed to dynamically adjust precision based on urgency or seamlessly integrate diverse data sources. Applying the Ideal Final Result (IFR) concept [92,93] drives innovation toward an AI system capable of providing instantaneous, accurate diagnoses with minimal human intervention. Function analysis allows for the optimization of diagnostic processes by breaking them down into functional components, while considering resource and constraint factors to ensure practicality and compliance [93–95]. Through TRIZ-guided problem-solving, AI in medical diagnosis can evolve to meet complex challenges effectively, ultimately improving patient outcomes and healthcare efficiency.

In sum, the successful integration of AI in medical diagnostics will require more than algorithmic excellence. It calls for a comprehensive vision that aligns technological capabilities with clinical realities, educational needs, ethical imperatives, and policy frameworks [96]. Future research should prioritize the development of interoperable multi-modal platforms, clinician-involved co-design models, AI-integrated curricula, explainable

Table 6. Challenges of AI applications in medical diagnosis.

| Prospects for enhancing AI in medical diagnosis | Details |
|---|---|
| Enhanced Data Integration | Integrating imaging, genomic, and clinical data to improve diagnostic accuracy and personalized treatment. |
| Real-time Feedback and Continuous Learning | AI systems that adapt to new data for improved prediction and diagnosis. |
| Validation in Clinical Settings | Ensuring AI tools are tested in practical environments to build trust among healthcare professionals. |
| Educational Initiatives | Integrating AI-focused courses in healthcare curricula to equip future practitioners. |
| Ethical Considerations | Emphasizing data privacy, informed consent, and transparency in AI processes. |
| Improved Interpretability and Explainability | Enhancing AI model clarity to help physicians understand and trust AI recommendations. |
| Standardized Evaluation Protocols | Developing comprehensive validation datasets and metrics for assessing AI performance. |
| TRIZ Framework Application | Using TRIZ principles to resolve AI design contradictions, improve diagnostic precision, and enhance system adaptability. |

The table summarizes future directions for improving AI integration in healthcare. It covers areas like enhanced data integration, real-time feedback, ethical considerations, educational initiatives, and the use of inventive frameworks like TRIZ to systematically overcome AI implementation barriers.

algorithm architectures, and rigorous validation pipelines. TRIZ offers a structured approach to navigate this complexity and identify optimal design solutions [97]. Through these coordinated efforts, AI can mature from a promising tool to a trusted partner in the delivery of precision diagnostics and patient-centered care. Table 6 summarizes the prospects discussed above.

## 8. Conclusion

Conclusively, the use of AI in medical diagnostics signifies revolutionary progress with significant ramifications for healthcare. Artificial intelligence demonstrates exceptional capabilities in multiple areas, such as forecasting and identifying diseases, creating customized treatment strategies, and handling extensive datasets in subjects like molecular biology and omics. AI algorithms exhibit remarkable precision in detecting abnormalities in medical pictures for cancer diagnosis, facilitating timely intervention and enhancing patient outcomes. The field of dental medicine is greatly improved using AI-powered technologies that boost the accuracy of diagnosis, treatment planning, and patient care. AI is used to assess patient data and create personalized treatment plans that are successful and have minimal negative effects. Furthermore, AI simplifies the handling and examination of intricate datasets in molecular biology and omics, hastening the process of discovering new drugs and enhancing our comprehension of disease mechanisms. The ongoing development of AI has the potential to transform healthcare delivery by integrating it into medical diagnostics. This integration offers the possibility of more accurate diagnoses, tailored therapies, and eventually, improved patient outcomes. Nevertheless, it is imperative to tackle obstacles such as data privacy, algorithm bias, and legal issues to guarantee the responsible and ethical implementation of AI in the field of healthcare.

## Author contributions

Conceptualization, P.L.C., V.V., B.K.M.R., b.R.A.N.H., P.T., and J.A.Y.; data curation, P.L.C., V.V., B.K.M.R., b.R.A.N.H., P.T., and J.A.Y., formal analysis, P.L.C., V.V., B.K.M.R., b.R.A.N.H., P.T., and J.A.Y., funding acquisition, P.L.C. amd J.A.Y., investigation, P.L.C. and V.V., methodology, P.L.C., V.V., B.K.M.R., and J.A.Y., project administration, P.L.C., V.V., B.K.M.R., b.R.A.N.H., P.T., and J.A.Y., resources, P.L.C., V.V., b.R.A.N.H., P.T., and J.A.Y., software, P.L.C., V.V., b.R.A.N.H., P.T., and J.A.Y., supervision, P.L.C., validation, P.L.C., V.V., B.K.M.R., b.R.A.N.H., P.T., and J.A.Y., visualization, P.L.C., V.V., b.R.A.N.H., P.T., and J.A.Y., writing – original draft, P.L.C. and V.V., writing – review & editing P.L.C., F.Y.K., and J.A.Y.

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## References

[1] Rao KS, Lean CP, Ng PK, et al. AI and ML in IR4.0: a short review of applications and challenges. Malaysian J Sci Adv Technol. 2024;4:141–148. doi: 10.56532/mjsat.v4i2.291
[2] Rao KS, Lean CP, Yuan KF, et al. Transformative applications of IoT in diverse industries: a mini review. Malaysian J Sci Adv Technol. 2024;4:130–140. doi: 10.56532/mjsat.v4i2.292
[3] Chong PL, Than YY, Ganesan S, et al. An overview of IoT based smart home surveillance and control system: challenges and prospects. Malaysian J Sci Adv Technol. 2023;4:54–66. doi: 10.56532/mjsat.v2iS1.121
[4] Chong PL, Chuah JH, Chow C-O, et al. Plant microbial fuel cells: a comprehensive review of influential factors, innovative configurations, diverse applications, persistent challenges, and promising prospects. Int J Green Energy. 2024;22(3):599–648. doi: 10.1080/15435075.2024.2421325
[5] Basir R, Islam GMN, Ng PK, et al. Exploring salary trends in data science, artificial intelligence, and machine learning: a comprehensive analysis. AIP Conference Proceedings. Vol. 3158; 2024. p. 020004. doi: 10.1063/5.0224376
[6] Khan MRB, Islam GMN, Ng PK, et al. Empowering decision-making in cardiovascular care: exploratory data analysis and predictive models for heart attack risk. AIP Conference Proceedings. Vol. 3158; 2024. p. 020005. doi: 10.1063/5.0224378
[7] Basir R, Islam GMN, Ng PK, et al. Optimizing sales strategy in the Indian automobile industry: predicting future car prices using machine learning and demographic data. AIP Conference Proceedings. Vol. 3158; 2024. p. 020003. doi: 10.1063/5.0224375
[8] Chong PL, Singh AK, Kok SL. Potential application of Aloe Vera-derived plant-based cell in powering wireless device for remote sensor activation. PLoS One. 2019;14(12):e0227153. doi: 10.1371/journal.pone.0227153
[9] Manoharan S, Lean CP, Li C, et al. IoT-enabled greenhouse systems: optimizing plant growth and efficiency. Malaysian J Sci Adv Technol. 2024;4:169–179. doi: 10.56532/mjsat.v4i2.294
[10] Ganesan S, Lean CP, Li C, et al. IoT-enabled smart weather stations: innovations, challenges, and future directions. Malaysian J Sci Adv Technol., 2024;4:180–190. doi: 10.56532/mjsat.v4i2.293
[11] Lean CP, Krishnan G, Li C, et al. A raspberry Pi-powered IoT smart farming system for efficient water irrigation and crop monitoring. Malaysian J Sci Adv Technol. 2024;4:149–158. doi: 10.56532/mjsat.v4i2.295
[12] Al-Badani MA, Chong PL, Lim HS. Enhancing microbial fuel cell performance with carbon powder electrode modifications for low-power sensors modules. Int J Renew Energy Dev. 2024;13(1):80–87. doi: 10.14710/ijred.2024.58977
[13] Esmaeilzadeh P. Use of AI-based tools for healthcare purposes: a survey study from consumers' perspectives. BMC Med Inform Decis Mak. 2020;20(1):170. doi: 10.1186/s12911-020-01191-1
[14] Wood E, Ange B, Miller D. Are we ready to integrate artificial intelligence literacy into the medical school curriculum: students and faculty survey. J Med Educ Curric Dev. 2021;8:23821205211024078. doi: 10.1177/23821205211024078
[15] Dabdoub F, Colangelo M, Aljumah M. Artificial intelligence in healthcare and biotechnology: a review of the Saudi experience. J Art Intel Cloud Comput; 2022. p. 1–6. doi: 10.47363/jaicc/2022(1)107
[16] Amedior N. Ethical implications of artificial intelligence in the healthcare sector. Adv Multidiscip Sci Res J Publ. 2023;36:1–12. doi: 10.22624/aims-/accrabespoke2023p1
[17] Gündüz E, Alçin ÖF, Kizilay A, et al. Radiomics and deep learning approach to the differential diagnosis of parotid gland tumours. Curr Opin Otolaryngol Head Neck Surg. 2022;30(2):107–113. doi: 10.1097/MOO.0000000000000782
[18] Bajwa J, Munir U, Nori A, et al. Artificial intelligence in healthcare: transforming the practice of medicine. Future Healthc J. 2021;8(2):e188–e194. doi: 10.7861/fhj.2021-0095
[19] Viscaino M, Maass JC, Delano PH, et al. Computer-aided diagnosis of external and middle ear conditions: a machine learning approach. PLoS One. 2020;15(3):e0229226. doi: 10.1371/journal.pone.0229226
[20] Liu M, Wu J, Wang N, et al. The value of artificial intelligence in the diagnosis of lung cancer: a systematic review and meta-analysis. PLoS One. 2023;18(3):e0273445. doi: 10.1371/journal.pone.0273445
[21] Wang K, Yu G, Xu C, et al. Accurate diagnosis of colorectal cancer based on histopathology images using artificial intelligence. BMC Med. 2021;19. doi: 10.1101/2020.03.15.992917
[22] Nazarian S, Glover B, Ashrafian H, et al. Diagnostic accuracy of artificial intelligence and computer-aided diagnosis for the detection and characterization of colorectal polyps: systematic review and meta-analysis. J Med Internet Res. 2021;23(7):e27370. doi: 10.2196/27370
[23] Chen P, Lu Y, Kang Y, et al. The accuracy of artificial intelligence in the endoscopic diagnosis of early gastric cancer: pooled analysis study. J Med Internet Res. 2022;24(5):e27694. doi: 10.2196/27694

[24] Shah K, Boyd JW, Broussard JR, et al. Adrenocortical function in children with brain tumors and pediatric hematopoietic cell transplantation recipients. J Pediatr Hematol Oncol. 2022;44(2):e469–e473. doi: 10.1097/mph.0000000000002220
[25] Kitamura S, Takahashi K, Sang Y, et al. Deep learning could diagnose diabetic nephropathy with renal pathological immunofluorescent images. Diagnostics (Basel). 2020;10(7):466. doi: 10.3390/diagnostics10070466
[26] Kenner BJ, Abrams ND, Chari ST, et al. Early detection of pancreatic cancer. Pancreas. 2021;50(7):916–922. doi: 10.1097/MPA.0000000000001882
[27] Suzuki H, Tokai Y, Yoshio T, et al. Artificial intelligence for cancer detection of the upper gastrointestinal tract. Dig Endosc. 2020;33(2):254–262. doi: 10.1111/den.13897
[28] Abe S, Oda I. Real-time pharyngeal cancer detection utilizing artificial intelligence: a journey from the proof of concept to the clinical use. Dig Endosc. 2020;33(4):552–553. doi: 10.1111/den.13833
[29] Kizildag Yirgin I, Koyluoglu YO, Seker ME, et al. Diagnostic performance of AI for cancers registered in a mammography screening program: a retrospective analysis. Technol Cancer Res Treat. 2022;21:15330338221075172. doi: 10.1177/15330338221075172
[30] Koch H, Larsen M, Bartsch H, et al. Artificial intelligence in breastscreen norway: a retrospective analysis of a cancer-enriched sample including 1254 breast cancer cases. Eur Radiol. 2023;33(5):3735–3743. doi: 10.1007/s00330-023-09461-y
[31] Dahlblom V, Dustler M, Tingberg A, et al. Breast cancer screening with digital breast tomosynthesis: comparison of different reading strategies implementing artificial intelligence. Eur Radiol. 2022;33(5):3754–3765. doi: 10.1007/s00330-022-09316-y
[32] Luchini C, Pea A, Scarpa A. Artificial intelligence in oncology: current applications and future perspectives. Br J Cancer. 2021;126(1):4–9. doi: 10.1038/s41416-021-01633-1
[33] Majid A, Alrasheedi MA, Alharbi AA, et al. Modified whale optimization algorithm for multiclass skin cancer classification. Mathematics. 2025;13(6):929–929. doi: 10.3390/math13060929
[34] Jafar A, Ul Abidin Z, Naqvi RA, et al. Unmasking colorectal cancer: a high-performance semantic network for polyp and surgical instrument segmentation. Eng Appl Artif Intell. 2024;138:109292–109292. doi: 10.1016/j.engappai.2024.109292
[35] Jung W, Lee K, Suh B, et al. Deep learning for osteoarthritis classification in temporomandibular joint. Oral Dis. 2023;29(3):1050–1059. doi: 10.1111/odi.14056
[36] Song Y, Jeong H, Kim C, et al. Comparison of detection performance of soft tissue calcifications using artificial intelligence in panoramic radiography. Sci Rep. 2022;12(1):19115. doi: 10.1038/s41598-022-22595-1
[37] Shan T, Tay F, Gu L. Application of artificial intelligence in dentistry. J Dent Res. 2021;100(3):232–244. doi: 10.1177/0022034520969115
[38] Tran B, Vu G, Ha G, et al. Global evolution of research in artificial intelligence in health and medicine: a bibliometric study. J Clin Med. 2019;8(3):360. doi: 10.3390/jcm8030360
[39] Hung K, Montalvao C, Tanaka R, et al. The use and performance of artificial intelligence applications in dental and maxillofacial radiology: a systematic review. Dentomaxillofac Radiol. 2020;49(1):20190107. doi: 10.1259/dmfr.20190107
[40] Warin K, Limprasert W, Suebnukarn S, et al. AI-based analysis of oral lesions using novel deep convolutional neural networks for early detection of oral cancer. PLoS One. 2022;17(8):e0273508. doi: 10.1371/journal.pone.0273508
[41] Xiao Y, Liang Q, Zhou L, et al. "Construction of a new automatic grading system for jaw bone mineral density level based on deep learning using cone beam computed tomography,". Sci Rep. 2022;12(1):12841. doi: 10.1038/s41598-022-16074-w
[42] Kar A, Wreesmann VB, Shwetha V, et al. Improvement of oral cancer screening quality and reach: the promise of artificial intelligence. J Oral Pathol Med. 2020;49(8):727–730. doi: 10.1111/jop.13013
[43] Abesi F, Sadat Jamali A, Zamani M. Accuracy of artificial intelligence in the detection and segmentation of oral and maxillofacial structures using cone-beam computed tomography images: a systematic review and meta-analysis. Pol J Radiol. 2023;88:e256–e263. doi: 10.5114/pjr.2023.127624
[44] Cai Y, Xie Y, Zhang S, et al. Prediction of postoperative recurrence of oral cancer by artificial intelligence model: multilayer perceptron. Head Neck. 2023;45(12):3053–3066. doi: 10.1002/hed.27533
[45] Ilhan B, Lin K, Guneri P, et al. Improving oral cancer outcomes with imaging and artificial intelligence. J Dent Res. 2020;99(3):241–248. doi: 10.1177/0022034520902128
[46] Khatabi A, Tmiri A, Serhir A. An effective system for content MRI brain image retrieval using angular radial transform. IJCA. 2015;117(24):29–32. doi: 10.5120/20705-3607
[47] Figuracion K, Jung W, Martha S. Ischemic stroke risk among adult brain tumor survivors: evidence to guide practice. J Neurosci Nurs. 2021;53(5):202–207. doi: 10.1097/jnn.0000000000000606
[48] Haq I, Aprianto D, Susilo R, et al. Corticosteroid therapy for brain tumor patients with adrenal insufficiency. Open Access Maced J Med Sci. 2021;9(F):31–35. doi: 10.3889/oamjms.2021.5597
[49] Esmaeili M, Vettukattil R, Banitalebi H, et al. Explainable artificial intelligence for human-machine interaction in brain tumor localization. J Pers Med. 2021;11(11):1213. doi: 10.3390/jpm11111213
[50] Sultan H, Salem N, Al-Atabany W. Multi-classification of Brain Tumor Images Using Deep Neural Network. IEEE Access. Vol. 7; 2019. p. 69215–69225. doi: 10.1109/access.2019.2919122
[51] Kothandaraman V. Binary swallow swarm optimization with convolutional neural network brain tumor classifier for magnetic resonance imaging images. Concurr Comput 2023;35(10). doi: 10.1002/cpe.7661

[52] Venkatachalam K, Siuly S, Bačanin N, et al. An Efficient Gabor Walsh-Hadamard Transform Based Approach for Retrieving Brain Tumor Images from MRI. IEEE Access. Vol. 9; 2021. p.119078–119089. doi: 10.1109/access.2021.3107371
[53] Cheng J, Yang W, Huang M, et al. Retrieval of brain tumors by adaptive spatial pooling and fisher vector representation. PLoS One. 2016;11(6):e0157112. doi: 10.1371/journal.pone.0157112
[54] Aswani K, Menaka D. A dual autoencoder and singular value decomposition based feature optimization for the segmentation of brain tumor from mri images. BMC Med Imaging. 2021;21(1). doi: 10.1186/s12880-021-00614-3
[55] Xiao Y, Fortin M, Unsgård G, et al. Retrospective evaluation of cerebral tumors (resect): a clinical database of pre-operative MRI and intra-operative ultrasound in low-grade glioma surgeries. Med Phys. 2017;44(7):3875–3882. doi: 10.1002/mp.12268
[56] Juvekar P, Dorent R, Kögl F, et al. ReMIND: the brain resection multimodal imaging database. medRxiv (Cold Spring Harbor Lab). 2023;11(1):494. doi: 10.1101/2023.09.14.23295596
[57] Wang C, Zhu X, Hong J, et al. Artificial intelligence in radiotherapy treatment planning: present and future. Technol Cancer Res Treat. 2019;18:1533033819873922. doi: 10.1177/1533033819873922
[58] Hussein M, Heijmen B, Verellen D, et al. Automation in intensity modulated radiotherapy treatment planning—a review of recent innovations. Br J Radiol. 2018;91(1092):20180270. doi: 10.1259/bjr.20180270
[59] Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. J Dent Res. 2020;99(7):769–774. doi: 10.1177/0022034520915714
[60] Qiu H, Ding S, Liu J, et al. Applications of artificial intelligence in screening, diagnosis, treatment, and prognosis of colorectal cancer. Curr Oncol. 2022;29(3):1773–1795. doi: 10.3390/curroncol29030146
[61] Sibolt P, Andersson L, Calmels L, et al. Clinical implementation of artificial intelligence-driven cone-beam computed tomography-guided online adaptive radiotherapy in the pelvic region. Phys Imaging Radiat Oncol. 2021;17:1–7. doi: 10.1016/j.phro.2020.12.004
[62] Pendy B. Artificial intelligence in health sector of USA. JISS. 2023;4(03):200–208. doi: 10.59141/jiss.v4i03.791
[63] Fröhlich H, Balling R, Beerenwinkel N, et al. From hype to reality: data science enabling personalized medicine. BMC Med. 2018;16(1):150. doi: 10.1186/s12916-018-1122-7
[64] Abatal A, Korchi A. Transforming healthcare systems with artificial intelligence: revolutionizing efficiency, quality, and patient care. Research Square. 2023. doi: 10.21203/rs.3.rs-3175341/v1
[65] Maassen O, Fritsch S, Palm J, et al. Future medical artificial intelligence application requirements and expectations of physicians in German university hospitals: web-based survey. J Med Internet Res. 2021;23(3):e26646. doi: 10.2196/26646
[66] Salih S, Elliyanti A, Alkatheeri A, et al. The role of molecular imaging in personalized medicine. J Pers Med. 2023;13(2):369. doi: 10.3390/jpm13020369
[67] Preuss K, Thach N, Liang X, et al. Using quantitative imaging for personalized medicine in pancreatic cancer: a review of radiomics and deep learning applications. Cancers (Basel). 2022;14(7):1654. doi: 10.3390/cancers14071654
[68] Al-Ali F, Polesie S, Paoli J, et al. Attitudes towards artificial intelligence among dermatologists working in saudi arabia. Dermatol Pract Concept. 2022;13(1). doi: 10.5826/dpc.1301a35
[69] Oh J, Lee J, Eun S, et al. New trends in innovative technologies applying artificial intelligence to urinary diseases. Int Neurourol J. 2022;26(4):268–274. doi: 10.5213/inj.2244280.140
[70] Kumar Y, Koul A, Singla R, et al. Artificial intelligence in disease diagnosis: a systematic literature review, synthesizing framework and future research agenda. J Ambient Intell Humaniz Comput. 2022;14(7):8459–8486. doi: 10.1007/s12652-021-03612-z
[71] Deserno Né Lehmann TM, Handels H, Maier-Hein Né Fritzsche KH, et al. Viewpoints on medical image processing: from science to application. Curr Med Imaging Rev. 2013;9(2):79–88. doi: 10.2174/1573405611309020002
[72] Nishida N, Kudo M. Artificial intelligence in medical imaging and its application in sonography for the management of liver tumor. Front Oncol. 2020;10:594580. doi: 10.3389/fonc.2020.594580
[73] Park W, Park J. History and application of artificial neural networks in dentistry. Eur J Dent. 2018;12(4):594–601. doi: 10.4103/ejd.ejd_325_18
[74] Emin E, Emin E, Papalois A, et al. Artificial intelligence in obstetrics and gynaecology: is this the way forward? In Vivo. 2019;33(5):1547–1551. doi: 10.21873/invivo.11635
[75] Yuan Q, Zhang H, Deng T, et al. Role of artificial intelligence in kidney disease. Int J Med Sci. 2020;17(7):970–984. doi: 10.7150/ijms.42078
[76] Larrazabal A, Nieto N, Peterson V, et al. Gender imbalance in medical imaging datasets produces biased classifiers for computer-aided diagnosis. Proc Natl Acad Sci USA. 2020;117(23):12592–12594. doi: 10.1073/pnas.1919012117
[77] Gaczek P, Pozharliev R, Leszczyński G, et al. Overcoming consumer resistance to ai in general health care. J Interact Mark. 2023;58(2–3):321–338. doi: 10.1177/10949968221151061
[78] Ali MU, Zafar A, Tanveer J, et al. Deep learning network selection and optimized information fusion for enhanced COVID-19 detection. Int J Imaging Syst Technol. 2024;34(2). doi: 10.1002/ima.23001
[79] Jafar A, Ghafoor A, Kim J, et al. HeartEnsembleNet: an innovative hybrid ensemble learning approach for cardiovascular risk prediction. Healthcare. 2025;13(5):507–507. doi: 10.3390/healthcare13050507
[80] Han Z. The application and challenges of artificial intelligence in brain tumor recognition. ACE. 2023;17(1):17–22. doi: 10.54254/2755-2721/17/20230904

[81] Bi W, Hosny A, Schabath M, et al. Artificial intelligence in cancer imaging: clinical challenges and applications. CA Cancer J Clin. 2019;69(2):127–157. doi: 10.3322/caac.21552

[82] Musa I, Afolabi L, Zamit I, et al. Artificial intelligence and machine learning in cancer research: a systematic and thematic analysis of the top 100 cited articles indexed in scopus database. Cancer Control. 2022;29:10732748221095946. doi: 10.1177/10732748221095946

[83] Zheng D, He X, Jing J. Overview of artificial intelligence in breast cancer medical imaging. J Clin Med. 2023;12(2):419. doi: 10.3390/jcm12020419

[84] Veeraraghavan V, Minervini G, Russo D, et al. Assessing artificial intelligence in oral cancer diagnosis: a systematic review. J Craniofac Surg. 2024;35(8):2397–2403. doi: 10.1097/scs.0000000000010663

[85] Jan Z, Assadi F, Abd-Alrazaq A, et al. Artificial intelligence for the prediction and early diagnosis of pancreatic cancer: scoping review. J Med Internet Res. 2023;25:e44248. doi: 10.2196/44248

[86] Halat D, Shami R, Daud A, et al. Artificial intelligence readiness, perceptions, and educational needs among dental students: a cross-sectional study. Clin Exp Dent Res. 2024;10(4):e925. doi: 10.1002/cre2.925

[87] Zhang B, Shi H, Wang H. Machine learning and AI in cancer prognosis, prediction, and treatment selection: a critical approach. J Multidiscip Healthc. 2023;16:1779–1791. doi: 10.2147/jmdh.s410301

[88] Chong PL, Ganesan S, Ng PK, et al. A TRIZ-adopted development of a compact experimental board for the teaching and learning of operational amplifier with multiple circuit configurations. Sustainability. 2022;14(21):14115. doi: 10.3390/su142114115

[89] Chong PL, Ismail D, Ng PK, et al. A TRIZ approach for designing a smart lighting and control system for classrooms based on counter application with dual PIR sensors. Sensors. 2024;24(4):1177–1177. doi: 10.3390/s24041177

[90] Ng PK, Chong PL, Yeow JA, et al. Ergonomic work from home recommendations using TRIZ. In: Human Factors in Engineering Manufacturing Systems, Automation, and Interactions. Boca Raton: Taylor & Francis; 2023. p. 65–82. Available from: https://www.taylorfrancis.com/chapters/edit/10.1201/9781003383444-4/ergonomic-work-home-recommendations-using-triz-poh-kiat-ng-peng-lean-chong-jian-ai-yeow-yu-jin-ng-robert-jeyakumar-nathan?context=ubx&refId=f08c3c55-81f5-4d04-a5ad-447a485f1096

[91] Ng PK, Jee KS. Design and development of an ergonomic milling machine control knob using TRIZ principles. Am J Appl Sci. 2016;13(4):451–458. doi: 10.3844/ajassp.2016.451.458

[92] Kang CQ, Ng PK, Liew KW. A TRIZ-integrated conceptual design process of a smart lawnmower for uneven grassland. Agronomy. 2022;12(11):2728. doi: 10.3390/agronomy12112728

[93] Lim SH, Ng PK. The design and development of a foldable wheelchair stretcher. Inventions. 2021;6(2):35. doi: 10.3390/inventions6020035

[94] Lim SH, Ng PK. Synthesisation of design features for multifunctional stretcher concepts. J Med Eng Technol. 2021;45(2):145–157. doi: 10.1080/03091902.2021.1873442

[95] Phuah ZY, Ng PK, Tay CH, et al. Development and usability evaluation of inventive and repurposable children's furniture. Inventions. 2025;10(1):20. doi: 10.3390/inventions10010020

[96] Basir R, et al. Accelerating electric vehicle adoption on Malaysian islands: lessons from Japan's islands of the future initiative. Lect Notes Electr Eng. 2024;1123:109–115. doi: 10.1007/978-981-99-9005-4_14

[97] Selvanesan EN, Liew KW, Tay CH, et al. A review of the performance of smart lawnmower development: theoretical and practical implications. Designs. 2025;9(3):55. doi: 10.3390/designs9030055