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FACULTY OF ELECTRICAL ENGINEERING

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FACULTY OF ELECTRICAL ENGINEERING

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PREFACE

The Third International Conference “Electrical Engineering, Technology, Informatics, Mechanical Engineering and Automation – Technical Sciences in the Service of the Economy, Education and Industry” (ETIMA’25), organized by the Faculty of Electrical Engineering at the “Goce Delchev” University – Shtip, represents a significant scientific event that enables interdisciplinary exchange of knowledge and experience among researchers, professors, and experts in the field of technical sciences. The conference was held in an online format and brought together 78 authors from five different countries.

The ETIMA conference aims to establish a forum for scientific communication, encouraging multidisciplinary collaboration and promoting technological innovations with direct impact on modern life. Through the presentation of scientific papers, participants shared the results of their research and development activities, contributing to the advancement of knowledge and practice in relevant fields.
The first ETIMA conference was organized four years ago, featuring 40 scientific papers. The second conference took place in 2023 and included over 30 papers. ETIMA’25 continued this scientific tradition, presenting more than 40 papers that reflect the latest achievements in electrical engineering, technology, informatics, mechanical engineering, and automation.

At ETIMA’25, papers were presented that addressed current topics in technical sciences, with particular emphasis on their application in industry, education, and the economy. The conference facilitated fruitful discussions among participants, encouraging new ideas and initiatives for future research and projects.

ETIMA’25 reaffirmed its role as an important platform for scientific exchange and international cooperation. The organizing committee extends sincere gratitude to all participants for their contribution to the successful realization of the conference and its scientific value.

We extend our sincerest gratitude to all colleagues who, through the presentation of their papers, ideas, and active engagement in discussions, contributed to the success and scientific significance of ETIMA’25.

The Organizing Committee of the Conference

ПРЕДГОВОР

Третата меѓународна конференција „Електротехника, Технологија, Информатика, Машинство и Автоматика – технички науки во служба на економијата, образованието и индустријата“ (ЕТИМА’25), организирана од Електротехничкиот факултет при Универзитетот „Гоце Делчев“ – Штип, претставува значаен научен настан кој овозможува интердисциплинарна размена на знаења и искуства меѓу истражувачи, професори и експерти од техничките науки. Конференцијата се одржа во онлајн формат и обедини 78 автори од пет различни земји.

Конференцијата ЕТИМА има за цел да создаде форум за научна комуникација, поттикнувајќи мултидисциплинарна соработка и промовирајќи технолошки иновации со директно влијание врз современото живеење. Преку презентација на научни трудови, учесниците ги споделуваат резултатите од своите истражувања и развојни активности, придонесувајќи кон унапредување на знаењето и практиката во релевантните области.

Првата конференција ЕТИМА беше организирана пред четири години, при што беа презентирани 40 научни трудови. Втората конференција се одржа во 2023 година и вклучи над 30 трудови. ЕТИМА’25 продолжи со истата научна традиција, презентирајќи повеќе од 40 трудови кои ги отсликуваат најновите достигнувања во областа на електротехниката, технологијата, информатиката, машинството и автоматиката.

На ЕТИМА’25 беа презентирани трудови кои обработуваат актуелни теми од техничките науки, со посебен акцент на нивната примена во индустријата, образованието и економијата. Конференцијата овозможи плодна дискусија меѓу учесниците, поттикнувајќи нови идеи и иницијативи за идни истражувања и проекти.

ЕТИМА’25 ја потврди својата улога како значајна платформа за научна размена и интернационална соработка. Организациониот одбор упатува искрена благодарност до сите учесници за нивниот придонес кон успешната реализација на конференцијата и нејзината научна вредност. Конференцијата се одржа онлајн и обедини седумдесет и осум автори од пет различни земји.

Изразуваме голема благодарност до сите колеги кои со презентирање на своите трудови, идеи и активна вклученост во дискусиите придонесоа за успехот на ЕТИМА’25 и нејзината научна вредност.

Организационен одбор на конференцијата

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APPLICATION OF ARTIFICIAL INTELLIGENCE IN DENTAL MEDICINE

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Abstract

There are four key sectors in which artificial intelligence is currently applied or has the potential to significantly influence the future of dentistry. Through this method, systems become capable of making predictions and making decisions based on previously collected information, which is very useful in diagnosing and treating diseases. AI systems operate by processing extensive labeled training datasets, identifying correlations and patterns, and utilizing these findings to make predictions about future conditions. The first and most critical application of AI in dentistry is in diagnostics, where it enables the analysis of large volumes of data, such as digital radiographs, 3D models, and photographs, allowing for the identification of anomalies that may not be visible to the naked eye. The second application is in treatment planning, where AI assists in developing customized treatment plans based on a patient's unique anatomical features, medical history, and anticipated outcomes. This technology also supports the accurate placement of dental implants and orthodontic appliances. The third area involves the analysis and management of data, which enhances the scheduling of appointments, document organization, and insurance status tracking. Finally, AI plays a vital role in the education of future dentists by providing realistic clinical simulations and virtual assistants, enabling students to practice complex procedures in a simulated environment that reflects real-world conditions. These simulations not only reduce the risk of errors during patient care but also facilitate ongoing and individualized learning experiences. In conclusion, we can say that artificial intelligence opens up new aspects and perspectives in modern dentistry.

Keywords:

artificial intelligence, virtual learning, artificial intelligence in dentistry, clinical simulations

Introduction

In the modern era, dental medicine is witnessing a notable change propelled by state-of-the-art innovations in technologies such as artificial intelligence (AI), virtual reality (VR), and teledentistry. These advancements not only elevate the standard of patient care but also allow dental professionals to offer more customized and sophisticated services.[1,2]
This narrative review aimed to evaluate the uses, roles, and accuracy of Arteficial Inteligence (AI) in different areas of dental medicine. The review describes the classification of AI, provides a summary of AI applications in dentistry and intended to assist dental professionals in better comprehending AI as a tool to enhance their everyday dental practice with improved efficiency.
For this review, an extensive research of electronic databases, such as Google Scholar, PubMed, Medline, Scopus and Web of Science, was conducted to identify relevant literature, dominantly in English, covering publications from 2015 to 2025.
To identify abnormalities such as caries cavities, bone loss, or malignancies with enhanced accuracy at an earlier stage, AI-driven tools are being used more effectively than conventional

techniques. By analyzing historical data and individual patient factors, AI can forecast the potential for future dental and oral diseases, enabling timely intervention and preventive measures.[3]
Artificial Intelligence is revolutionizing the dental industry by improving diagnostic accuracy, customizing treatment strategies, forecasting potential dental problems, and increasing operational productivity. We expect that AI technology will keep advancing, further transforming dental practices and elevating patient care.[4]
Artificial intelligence (AI) represents a broad array of emerging technologies that continue to affect our everyday lives and working activities. The development of AI facilitates the analysis of large volumes of data, which yields trustworthy information and improves the decision-making process.
AI technology has made a notable impact on the healthcare field due to the demand for accurate diagnoses and superior patient care. The existing applications of AI in clinical dentistry have been introduced and summarized. In the future, the AI-driven comprehensive care system is expected to establish high-quality patient care and promote innovative research and development, thereby enabling advanced decision support tools.[5]

Artificial Intelligence in Dental Medicine

Artificial intelligence is characterized by the replication of human cognitive processes by machines, notably computer systems. By processing large quantities of data and detecting patterns, AI systems can evaluate and predict outcomes with a precision that carries substantial promise for both medical and dental uses.
With adequate training, artificial intelligence can execute tasks with enhanced precision and accuracy compared to humans. Although it is a relatively recent technology, AI is progressively being utilized across different medical fields to diagnose different diseases, analyze results, and assist healthcare professionals in attaining favorable patient outcomes. AI applications in healthcare can be categorized into two types: virtual and robotic. [6]
The growing integration of advanced technology in clinical practice enhances the precision, efficiency, and comfort of dental care for patients. Various technological advancements have positively impacted dentistry, including intraoral scanners, 3D printers for denture fabrication, robotic surgery, regenerative dentistry, virtual reality and artificial intelligence. The utilization of AI in dentistry is increasingly recognized in areas such as imaging and pathology, dental radiology, caries detection, electronic record management, and robotic assistance.[7,8]
However, AI can provide support to dentists in their clinical decision-making and assist in diagnosing patients to offer the best possible care. Additionally, it has the potential to scrutinize any abnormal changes in the oral mucosa. Presently, the utilization of intraoral scanners and cameras in dental offices has significantly facilitated the assessment and planning of care. Convolutional neural networks (CNN) will also aid in streamlining diagnosis, while an artificial neural network (ANN), which is a statistical model or computer program, can imitate the neural network of the human brain to perform cognitive functions such as problem-solving.[9]
AI in dentistry encompasses three primary cognitive functions:

- Education: AI systems engage in the processing and analysis of data to derive insights. As time progresses, they enhance their ability to identify trends and patterns within clinical datasets, thereby advancing diagnostic and treatment methodologies.
- Logical Deduction: This phase entails making reasoned conclusions derived from data analysis. AI is capable of evaluating various treatment results and suggesting the most effective procedures through sophisticated algorithms.

• Self-Improvement: By means of ongoing data feedback, AI systems enhance their results and reduce inaccuracies, thereby increasing their precision and efficiency with every new dataset.[4]

Machine Learning and Deep Learning in Dentistry

A common variant of artificial intelligence is known as machine learning. This implies that a computer can learn to perform tasks by reviewing numerous examples. A more sophisticated form is referred to as deep learning, where the computer applies multiple layers of "cognitive processes" (known as neural networks) to interpret aspects such as images or patterns. For instance, deep learning can aid a computer in identifying signs of tooth decay in X-ray images.[10]

The primary function of these networks is to process complex images by extracting features from different layers of filters.[11]

In one of the studies, the comparison between traditional regression models and machine learning-based prediction models indicated favorable performance and can be utilized to predict early childhood caries (ECC), identify high-risk groups for ECC and implement proactive preventive treatments. Chang et al. [12] developed an automated technique for staging periodontitis that can assist dental professionals in diagnosing and systematically monitoring periodontitis accurately on panoramic radiographs.

AI systems in the field of dentistry function through two essential methodologies:

• Machine Learning (ML): This method allows computers to learn from extensive datasets, recognize patterns, and make well-informed predictions. It is particularly effective in disease detection, allowing for early diagnosis before symptoms are clinically observable.

• Deep Learning (DL): A more intricate subset of ML, deep learning harnesses neural networks to analyze large imaging datasets and identify complex patterns that are often missed by human vision—an important feature in the realm of precision dentistry.

These technologies are presently utilized for image-based diagnostics, such as the analysis of radiographs, and for formulating personalized treatment plans that are adapted to the specific medical history and clinical needs of each patient.

AI Algorithms in Dental Applications

The use of Artificial Intelligence can effectively address knowledge deficiencies while also decreasing expenses and augmenting advantages. AI is often applied in the field of disease management to assess treatment results and enable precision medicine.[13] These innovative machine-learning algorithms are formidable analytical instruments that support clinicians in interpreting and analyzing emotional states.[14]

However, recent developments in AI algorithms, particularly deep learning models, have exhibited efficiency in resolving a multitude of problems. These algorithms require extensive CPU and memory resources, which restricts standard CPUs from achieving the anticipated performance levels. [15]

Furthermore, healthcare professionals should be prepared to articulate the results and forecasts of an AI system and possess a complete understanding of them. The interpretability of AI technology is a widely recognized challenge, and substantial advancements are necessary before certain algorithms, such as neural networks, can provide clinical diagnoses or treatment recommendations with absolute transparency.[16]

The integration of AI within dental workflows has been driven forward by cutting-edge algorithmic models, especially:

1. Convolutional Neural Networks (CNN)
CNNs represent deep learning frameworks that are fine-tuned for visual data analysis. They can derive important features from dental radiographs and 3D scans to recognize caries, tumors, and anatomical discrepancies. CNNs demonstrate superior diagnostic efficacy relative to traditional assessments performed by dental professionals, identifying early-stage conditions with outstanding accuracy

2. Artificial Neural Networks (ANN)
Artificial Neural Networks (ANNs) simulate the functions of the human brain and are vital in predictive modeling within dentistry. For example, in the area of orthodontics, ANNs can forecast the paths of tooth movement, which aids in accurate treatment planning. They also analyze patient histories, genetic factors, and past treatment results to create customized therapeutic recommendations.

3. *Clinical Decision Support Systems (CDSS)*
CDSS are integrated systems that use AI algorithms, including ANNs and others, to assist clinicians in making informed decisions. These platforms evaluate patient-specific data—such as medical history, diagnostic information, and genomic details—to propose optimal treatment approaches based on evidence-based practices, thus enhancing diagnostic accuracy and treatment outcomes.

Major Roles of AI in Dentistry

AI is redefining numerous operational areas within dentistry:
1. Diagnostics
AI enhances diagnostic accuracy through the analysis of digital images (radiographs, 3D scans, clinical photographs) to identify subtle pathological changes. CNNs, in particular, are adept at detecting carious lesions, fractures, or tumors that are not visible to the naked eye, which allows for early and effective intervention.

- In radiology, CNNs can achieve accuracy levels of up to 99.45% in detecting posterior tooth caries.
- In orthodontics, ANNs can predict the necessity for tooth extractions in malocclusion cases with a precision of 80–93%.
- In oral pathology, CNNs demonstrate over 80% accuracy in identifying head and neck lesions, showcasing significant potential in oncology diagnostics.

2. Treatment Planning
AI customizes treatment protocols by analyzing anatomical data, medical histories, and predictive simulations. In orthodontics, AI tools visualize appliance placement and tooth movement, enabling clinicians to organize procedures with greater precision and reduced risk.

3. Administrative Management
AI-supported virtual assistants streamline operations like appointment scheduling, insurance processing, and document management. This automation decreases the administrative workload and enhances the efficiency of clinic workflows.

Artificial intelligence in periodontal treatment

Maintaining periodontal health requires the presence of healthy bone and the structures that support it. AI technology significantly aids in the early identification of periodontal disease and bone loss in teeth. Models utilizing the VGGNet-19 and GoogLeNet Inception-V3 architectures perform exceptionally well in illustrating and predicting the outcomes of periodontal trearment.[17]

Artificial intelligence in oral medicine and radiology

With the aid of AI, oral cavity lesions can be identified, treated, and classified as potentially altered mucosa that is experiencing either premalignant or malignant changes. During the mixed dentition stage, artificial neural networks and genetic algorithms are emerging as effective tools for accurately estimating the dimensions of unerupted canines and premolars, along with forecasting tooth surface loss. This loss of tooth surface is a prevalent concern that entails an irreversible, multifactorial, non-carious, physiological, pathological, or functional loss of dental hard tissues.[18]

Artificial intelligence in prosthodontics

RaPid, an innovative prosthodontic design tool, utilizes anthropological calculations, facial proportions, ethnic diversity, and patient preferences to craft the most visually appealing prosthesis.[19] RaPiD connects databases, knowledge-based systems, and computer-aided design through logic-based illustrations. The use of neural networks empowers dental labs to independently produce high-quality dental restorations that adhere to strict standards of fit, function and appearance in aesthetic context. Likewise, orofacial and craniofacial prostheses would be greatly impacted.[20]

Artificial intelligence in oral and maxillofacial surgery

The primary application of AI in oral surgery is robotic surgery, which replicates human movements and cognitive functions. Image-guided cranial surgery has demonstrated effectiveness in addressing tumors, foreign objects, biopsies, and dental implants. Oral implant procedures exhibit greater accuracy compared to freehand techniques, even when performed by skilled surgeons. Reports indicate reduced operating times, enhanced intraoperative precision, and safer handling of delicate structures.[21]

Artificial intelligence in orthodontic treatment

The implementation of radiography, intraoral scanners, and cameras allows for diagnostic and treatment planning through detailed analysis of the captured images. Consequently, the requirement for executing numerous laboratory tasks, such as taking patient impressions, has become redundant, and the results are generally more accurate than those obtained solely through human visual inspection. Algorithms and statistical evaluations can be applied to forecast tooth movement and the eventual results of treatment. One of the latest and most discussed innovations in orthodontic dentistry relates to the use of AI for creating tailored orthodontic treatment plans. Currently, AI is extensively applied in various stages of orthodontic treatment, including diagnosis, treatment planning, and therapy supervision. In the evaluation of craniofacial and dental irregularities, the use of three-dimensional scans and virtual models is advantageous. The use of three-dimensional scans facilitates the creation of aligners and the design of personalized treatment plans. AI-enhanced aligners provide precise and swift care.[22]

Artificial intelligence in pediatric dentistry

The implementation of pain control devices powered by Artificial Intelligence represents a modern and more rational approach to establishing an injection-free pediatric dentistry practice. Young patients can gain from the use of diverse virtual reality games, films, animations, and four-dimensional goggles as a means of behavior management.[23]

Artificial Intelligence in Endodontics

The application of AI-based techniques holds promise for aiding endodontists in the precise identification and analysis of complex root canal systems by detecting and segmenting root canals in radiographic images. The adoption of automated canal detection may offer numerous advantages, such as decreased treatment duration, increased efficiency, and enhanced precision. AI approaches, particularly machine learning, can utilize patient-specific information, encompassing clinical parameters, radiographic results, and treatment protocols, to create predictive models for evaluating the effectiveness of endodontic treatments.[24]

Teledentistry in Present-Day Practice

Teledentistry represents a notable shift by enabling remote consultations and diagnostics for patients.[25,26] It is particularly advantageous for underserved groups in rural or inaccessible areas.

Models of Teledentistry

• Real-time Consultations: Direct engagement between the dentist and patient via video or audio conferencing for immediate assessment.

• Store-and-Forward: Clinical data (for instance, radiographs and photographs) is collected and securely transmitted for asynchronous review by specialists.

Major Software Platforms

• Teledentix: Combines video conferencing, image sharing, scheduling, and electronic records into a single cohesive environment.

• MouthWatch TeleDent: Aids in remote diagnostics and ensures continuity of care through high-quality image sharing and clinical data transfer.

• VSee: A secure and easy-to-use platform for real-time video consultations, offering strong privacy measures and compatibility across various platforms.

Teledentistry fosters preventive care by offering educational consultations regarding oral hygiene practices and early disease prevention, which can lead to decreased treatment costs and fewer invasive procedures.

Although teledentistry offers numerous benefits, it also faces several challenges, including:

• Technological Infrastructure: Reliable internet connectivity and secure data processing platforms are necessary but often insufficient in remote locations.

• Data Security: It is essential to comply with privacy legislation and safeguard against cyberattacks.

• Legal and Ethical Concerns: Establishing liability for misdiagnoses or mistakes in AI-assisted treatments is a complex issue that requires clear regulations.

Education and AI-Based Training

AI and VR are reshaping dental education through:

• Simulations: Virtual environments that accurately reflect real clinical conditions allow students to practice procedures without risking patient safety.

• Personalized Learning: AI tailors educational content to match each learner's pace and knowledge, enhancing their competence and confidence.[27, 28]

Virtual Reality in Dentistry

The application of virtual reality is growing in:

• Training and Simulation: Boosting student readiness with immersive simulations of clinical scenarios.

• Surgical Planning: Enabling preoperative visualization of complex surgical interventions.

• Patient Education: Aiding patients in understanding procedures and reducing their anxiety.

• Rehabilitation: Managing dental phobias and anxiety through controlled exposure therapy in a virtual environment.

To successfully implement AI and teledentistry, it is essential to provide specialized education in technology as well as ethical practices. Dental curricula ought to incorporate principles of AI, skills for telehealth communication, and an understanding of cybersecurity to cultivate capable future practitioners.

Conclusion

In recent years, the integration of artificial intelligence, virtual reality, and teledentistry has significantly altered the landscape of dental medicine. AI enhances the quality of diagnostics, treatment planning, and precision in procedures. Teledentistry facilitates access to care for remote areas and increases efficiency, while virtual and augmented reality enhance clinical training and patient engagement. To ensure the complete integration of these innovations, sustained investment in research, regulatory measures, and dental education is necessary. These technologies herald a promising future—one in which dentistry is more individualized, precise, and accessible to everyone.

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