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Teeth and Technology: The Responsibility of Artificial Intelligence Techniques in the Dental Field- A Literature Review

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ABSTRACT: With the significant growth of modern technology and its integration into many different industries, especially in the healthcare sector, artificial intelligence is one of the critical methods contributing to the development of medical fields, including dentistry. It possesses important and influential techniques that contribute to improving the results of patient care, diagnosis, treatment planning, and tracking the spread of diseases. These techniques play a major role in assisting dentists in diagnosing patients with high efficiency and accuracy. In this review, artificial intelligence techniques in developing the field of dentistry will be reviewed by highlighting the most important literature in which these techniques are involved. A search was conducted in Web of Science, Scopus, and PubMed databases from 2018 to 2023, where many articles were found (n=432), and articles that did not meet the selection criteria were excluded, resulting in thirty included. These articles involve artificial intelligence techniques in six areas: periodontal, dental implantology, forensic dentistry, oral medicine and pathology, orthodontics, and diagnostics/dentistry. In addition, this review presents matters related to artificial intelligence in dentistry, including data security, ethical concerns, and developing dentists' skills. This article finds that deep learning methods are widely utilized in the growth of dentistry, as the results show the accuracy of the results obtained, which is equivalent to the accuracy of professionals, and that it contributes to reducing human errors and revolutionizing the improvement of patient outcomes.

Keywords: Artificial intelligence, Medical field, Machine Learning, Dentistry, Databases, Explainability.

1. INTRODUCTION

Dentistry is one of the branches of medicine that focuses on studying and diagnosing natural diseases of the mouth, jaw, face, and teeth and treating the patient by eliminating the issues to which the teeth are exposed [1-3]. Dentists are distinguished by their experience, as they are artists and craftsmen who treat dental problems using modern methods to maintain oral health and treat the issues of tooth decay and periodontitis. These physicians employ different techniques and materials to repair or replace damaged or missing teeth, dental implant surgery, and much more. Dentists apply many practices and treatments to prevent diseases and tooth and mouth decay through dental diagnostics and examinations [4][5]. In addition, dental correction services, fluoride treatments, maintaining gum health from infections, orthodontics, performing oral and jaw surgery, and treating oral cancers. At large, dentistry field plays a major role in maintaining oral health and eliminating all problems present in it. Therefore, patients must create a schedule that includes organized visits to the dentist to detect any defects in the mouth early and improve their health condition. Modern technology and applications are of great significance in developing healthcare services, and among these technologies are artificial intelligence methods [6-8]. This term is mainly associated with robotics and describes how this technology is used and programmed to imitate the human mind and perform many tasks [9][10]. The intersection between artificial intelligence techniques and healthcare organizations has generated major changes in medical fields [11][12]. These technologies have significantly revolutionized diagnosing and predicting diseases, developing treatment strategies, vaccines, and patient care. Artificial intelligence has become the tool that makes applications work like the human mind and at different levels, making them more experienced than humans.

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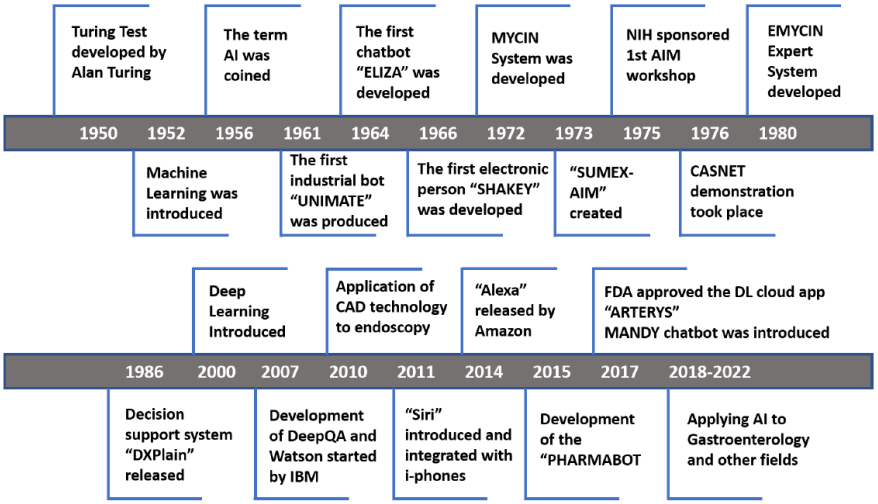

FIGURE 1. - Timeline of the development and use of artificial intelligence in healthcare [13].

The idea of artificial intelligence was launched in 1956 at Dartmouth. Since then, computational techniques such as reasoning, deep learning, adaptation, sharing, sensory understanding, and neural networks have played a major role in developing many industries. These techniques have many challenges and limitations, such as data access. Some methods can perform a role that typically includes human interpretation, decision-making, and generating algorithms to solve problems. In addition, these techniques have multiple applications in studying the behavior of data and discovering new disease patterns. Artificial intelligence has a prominent role in integrating computer-supported programs into healthcare and improving the performance of physicians and healthcare workers in diagnosing diseases [14][15]. Integrating artificial intelligence into the healthcare sector is not a recent idea. It began in the 1950s when the first attempt was made to use computers in developing this sector (see Figure 1). A study conducted by Jiang et al. [16] on the importance of artificial intelligence in the healthcare sector compares its performance in the past and present. It anticipates the development of this technology in the future. The authors sought to demonstrate the primary motivations for applying artificial intelligence in healthcare services, the types of data that are analyzed by AI-powered systems, as well as how this technology contributes to achieving meaningful clinical outcomes. The computing power generated by artificial intelligence is of excellent importance due to its enormous ability to analyze large amounts of digital data (see Figure 2). Many studies have explained the importance of artificial intelligence in analyzing big data. One of these studies is a study conducted by Amann et al. [17] on the possibilities of artificial intelligence in developing healthcare, where a multidisciplinary approach was relied upon to analyze the extent of the importance of artificial intelligence techniques in supporting decision systems—clinical focus on achieving meaningful clinical results. The authors conclude that these techniques have a critical role, but that healthcare professionals and legislators should be aware of these techniques' challenges and limitations. Artificial intelligence is changing medical practices by helping doctors diagnose diseases and generate clinical, diagnostic, and prognostic practices, as its immediate goal is to transform all healthcare services into a digital environment. In another study by Meskó et al. [18] about the meaning and importance of digital healthcare and how it affects the promotion of technological innovations in developing clinical expertise and diagnostic processes, a description was also made between traditional and digital healthcare, mentioning the matter of each one of them.

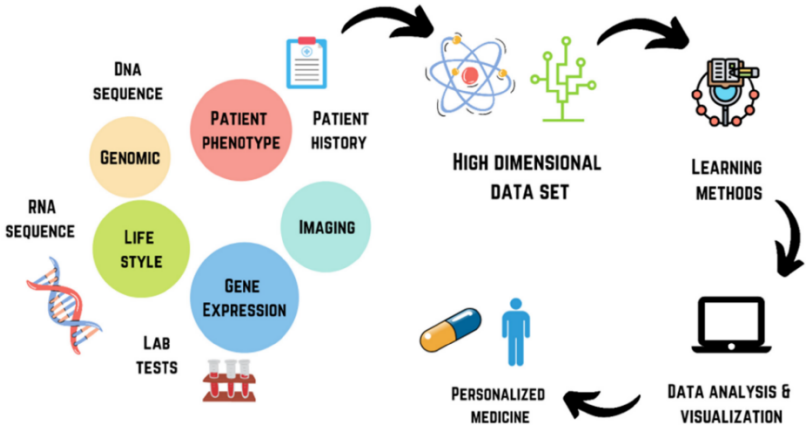

FIGURE 2. - Artificial intelligence analyzes patient data and customizes treatment [19].

Artificial intelligence is an essential branch of computer science that has the ability to imitate human cognitive abilities. Its main objective is to create machines that can learn from data so that they can solve problems. Making clinical decisions and diagnosing diseases are among the critical matters that artificial intelligence strategies seek to integrate into healthcare sectors. These methods have significant potential to assimilate extensive data, analyze it, and report it through processing mechanisms, guide clinical decisions, and find new information in the mass of huge medical data. Artificial intelligence has important methods that contribute to growing healthcare services and assist doctors in diagnosis and prediction, including machine learning, deep learning, artificial neural networks, expert systems, computer vision, and others. Algorithms are relied upon to predict outcomes based on datasets. These procedures are accomplished through machine learning, which facilitates the learning of machines so that they can solve issues without any human intervention. The most important artificial intelligence algorithm is the convolutional neural network (CNN), which is applied in processing large and complex images and is the most widely used in interpreting X-ray images and CT-scans [20][21]. Artificial neural networks (ANNs) have accurate computational power that depends on the quality and quantity of data. Patient care outcomes can be improved using AI techniques, as it can aid in diagnosis and reduce errors in clinical practice. Digital X-rays can be used because they have great potential to improve the diagnostic process in radiology and help doctors make real-time decisions with high accuracy and efficiency.

The main contribution of this article is a review of artificial intelligence techniques in developing traditional methods used in the dental field. These techniques have influential practices in improving the accuracy and efficiency of dentists' work and growing diagnostic tools. A search was conducted in Scopus, PubMed, and Web of Science databases from 2018 to 2023 to select a literature set and outline its role in integrating these techniques in improving clinical outcomes and patient care. The main motivations of this article are to integrate artificial intelligence techniques into dentistry to pursue early disease detection and personalized treatment planning and simplify administrative tasks, ultimately enhancing comprehensive patient care and developing health institutions. This review provides insight into the role of artificial intelligence techniques in advancing dental practice.

2. AI TECHNIQUES IN THE DENTAL FIELD

The importance and practices of artificial intelligence techniques in dentistry are increasing, marking the beginning of a new era of algorithms searching for new patterns in a large dataset with high accuracy and efficiency. The most notable of these algorithms are machine learning algorithms with exceptional capabilities in processing huge amounts of data and helping dentists diagnose dental and periodontitis and plan treatment. These techniques contribute to patient care through accurate dental diagnosis and reducing errors in clinical practices. Also, digital X-rays can be utilized, as they have significant potential to improve the diagnostic process in the domain of radiology with the help of artificial intelligence techniques [22-24]. Modern technology is increasingly integrated into dentistry, providing efficiency by reducing time and data management for diagnosis and treatment and improving patient results. Artificial intelligence can assist in improving dental care, in some cases allowing for earlier detection and more accurate diagnosis, more practical dental treatment planning, and suggested clinical decision-making. In addition, these techniques excel in image recognition, providing great practice in imaging and radiography. Deep learning models have a significant role in diagnosing dental diseases, as most studies apply these models [25][26]. The most famous of these models is the artificial neural network that learns independently to find complex features and new patterns that contribute to studying disease manners. Deep learning models can provide an environment for more accurate evaluations in dental and periodontitis disease detection tasks and assist dentists in making proper decisions. Prediction is one of the steps provided by artificial intelligence technologies, as it assists dentists in planning treatment, analyzing historical patient data, and providing high accuracy in diagnosing all disease cases. To simplify and automate all administrative procedures, natural language processing (NLP) algorithms are employed to facilitate communication between patients and dentists in a secure electronic environment [27][28].

The most critical tools applied in the dental imaging and classification of dental caries are convolutional neural networks (CNNs), as studies indicate that this tool has a remarkable ability to automatically learn hierarchical representations of data, which makes it a suitable tool for analyzing panoramic radiography images (see Figure 3). This tool offers architectures that play a role in the accurate and early detection of dental conditions for all age groups. In addition, this tool is characterized by multiple layers of convolutional and pooling operations to automatically extract features from dental images, as it is trained on huge datasets to classify all diseases of tooth caries, missing teeth, and gum diseases [29][30]. This tool is trained to recognize patterns and textures associated with teeth caries and dental restoration operations, to perform accurate classification and analyze patient data, and to make it more comfortable for dentists to complete the necessary procedures in real-time. The data utilized are X-rays, intraoral scanners, and other dental radiographs. The ability that distinguishes this tool is to distinguish minor changes that occur inside the mouth and in the structure and density of teeth, as the procedure contributes to determining the stages of caries and taking the necessary actions in real-time. This tool is vital in efficiently caring for patients, accelerating procedures and with high accuracy. Figure 3 illustrates the performance of a deep learning model in predicting dental caries utilizing panoramic radiograph images. Figure 4 shows an example of a panoramic radiograph images.

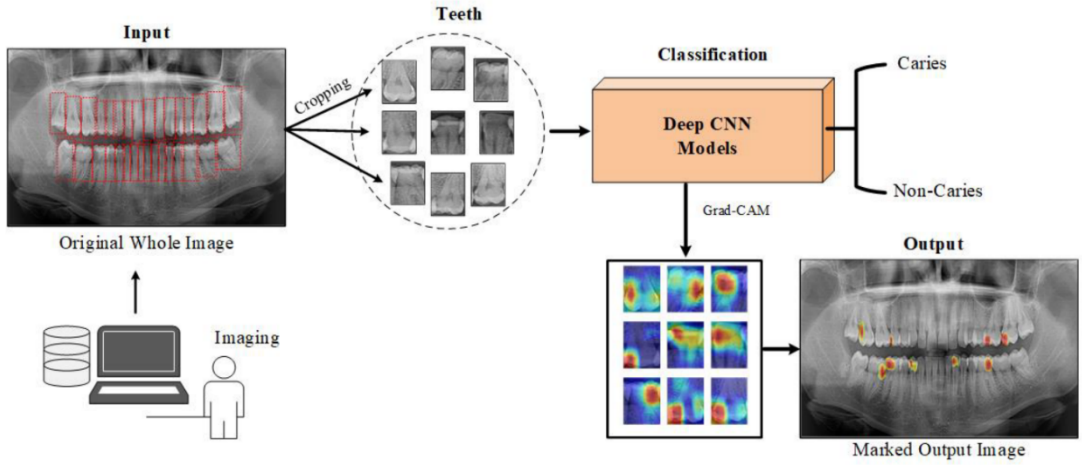

FIGURE 3. – Performance scheme for a DL model to predict dental caries using panoramic radiology images [31].

This section conducted a survey of the most critical literature in which artificial intelligence techniques are applied in diagnosing dental and periodontitis and collecting data and information. An extensive electronic search was performed in various digital databases: PubMed, Scopus, and Web of Science from 2018 to 2023. A search strategy was created for Medical Subject Headings (MeSH) and open terms, and then controlled and indexed descriptors were used for each utilizing the Boolean operators OR, AND, and NOT. A database of more than 400 studies is created, where criteria were set for selecting articles that use measurable results of artificial intelligence models and articles that appropriately describe these models. Studies that did not meet the selection criteria are excluded, which led to only 30 of them being included. The search was conducted randomly and sequentially employing the following phrases or descriptors: "artificial intelligence + dentistry," "artificial intelligence + dentistry + diagnosis," and "artificial intelligence + dentistry + treatment." The outcomes were filtered according to inclusion and exclusion criteria, relevance, topical relevance, and publication date. Articles published in other languages are excluded.

An example of the search process in the *Scopus* and *WoS* database:

The following terms with OR were used: "Artificial Intelligence", "computational intelligence", "Machine Learning", "Deep Learning", "Dental Radiography" joined by AND to the following words: "dental implants", "periodontics", "diagnostic imaging" "endodontics", "orthodontics", "oral surgery", "prosthodontics" "oral radiology", "maxillofacial surgery", and "forensic dentistry".

Exclusion criteria (articles that were excluded):

- Articles related to dentistry that do not mention artificial intelligence techniques.
- Pre-printed articles.
- Conference posters.
- Articles that only describe the AI model, i.e. without results.
- Review articles and AI perception survey articles.
- Letters to the editor.
- Conference articles.

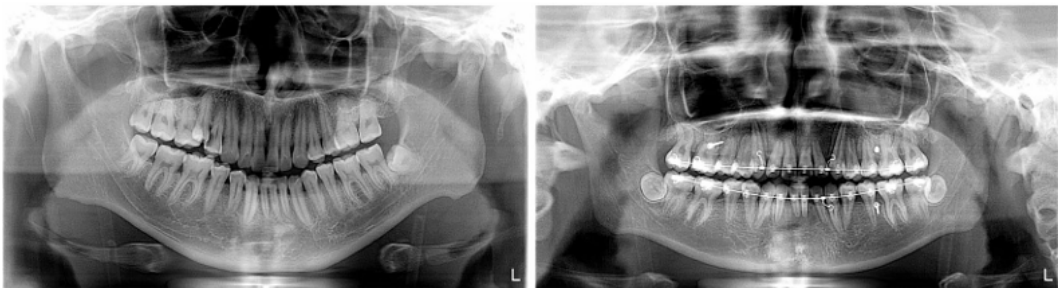

FIGURE 4. –Sample panoramic dental radiographs [32].

The selected articles were recorded in a table where the techniques used, the data (number of images or number of patients), the country and year of publication, the main objective of the article, and the results reached by the researchers,

such as sensitivity, accuracy, F1-score, and other results are highlighted. Table 1 illustrates the selected articles covering the topics of periodontology, dental implantology, forensic dentistry, oral medicine and pathology, orthodontics, dental diagnostics, and endodontics. Also, Table 1 indicates that most studies relied extensively on panoramic dental radiographs, while the most commonly used artificial intelligence techniques are deep learning models. Figure 5 illustrates the percentage of selected publications by year. Table 2 indicates the number of publications by country. Table 3 indicates the number of publications by journals.

Table 1. - Selected articles on the application of artificial intelligence in diagnosing dental and periodontitis.

Authors/Year	Country	Methods/ Architecture	Database Paper	Objective	Main result
***Lee et al.* 2018, [33]**	South Korea	DCNN	3000 periapical radiographic	Employing and analyzing the effectiveness of DCNN for detecting and diagnosing dental caries on periapical radiographs	The proposed algorithm achieved a diagnosis accuracy of 89%.
***Ha et al.* 2018, [34]**	South Korea	DT and SVM	667 implants in 198 patients	Machine learning algorithms were employed to diagnose 667 implant data for 198 patients over one year at Seoul National University Bundang Hospital.	The SVM algorithm performed competently by being implemented on 23 factors, earning an accuracy of 95%.
***Patcas et al.* 2018, [35]**	Switzerland	CNN	146 consecutive orthognathic patients	Training CNN to describe the effect of orthognathic treatment on facial attractiveness and age appearance (facial aesthetic analysis)	CNN method achieved excellent performance in describing the Impact of therapy on appearance.
***Kim et al.* 2019, [32]**	South Korea	DCNNs	12,179 images	A deep learning-based method was proposed to assist specialists in diagnosing periodontal bone loss in panoramic dental radiographs. DCNNs were employed to overcome the morphological variation of the lesions and imbalanced training dataset. This method has been trained, validated, and tested on a large group of panoramic dental radiographs.	The implementation of the suggested method was compared with the performance of dentists, as it achieved an F1 score of 0.75 on the test set, while the average performance of dental clinicians was 0.69.
***Tuzoff et al.*, 2019, [36]**	Russia	Faster R-CNN	1352	A novel solution based on CNNs in analyzing and	The proposed method achieved teeth detection

				diagnosing dental radiographs.	results of a sensitivity of 0.9941 and a precision of 0.9945. In addition, it reached a sensitivity of 0.9800 and a specificity of 0.9994 in teeth numbering.
***Krois et al.*, 2019, [37]**	Germany	DCNNs	2001 manually cropped image	DCNNs (VGG16 and Inception.v3) were applied and trained on panoramic dental radiographs to detect PBL. CNN was prepared and validated by repeated group shuffling ten times.	Implementation results with mean (SD) are: accuracy= 0.81(0.02) sensitivity= 0.81(0.04) specificity= 0.81(0.05)
***Chang et al.*, 2020, [38]**	South Korea	CNN+CAD	Three datasets:330, 115, and 73	A hybrid deep learning and computer-aided design approach was proposed to identify staging periodontitis on dental panoramic radiographs. The proposed method detects the jaw's radiographic bone level (or the CEJ level). This method was trained on more than 500 images, which were divided into 90% as training data and 10% as test data, and the grey values of these images were transformed by contrast-normalization.	Achieved Excellent effects in detecting staging periodontitis with a Pearson correlation coefficient with the diagnoses by radiologists of 0.73 and intraclass correlation of 0.91 overall for the whole jaw ($p < 0.01$)
***Yasa et al.*, 2020, [39]**	Türkiye	Faster R-CNN	1125 bite-wing radiographs	Proposing a system based on DL to automatically detect teeth numbering in gnawing images to help dentists perform the accurate numbering in less time.	Six hundred ninety-seven teeth were perfectly numbered employing the deep CNN system. The F1-score=0.9515, accuracy=0.9293, and sensitivity=0.9748.
***Yu et al.*, 2020, [40]**	China	UCDA+ResNet-FPN	1368 oral images	Employing a UCDA framework is initialized with a ResNet-FPN-based	Results of the proposed model: accuracy =92.25

				backbone to detect caries on the first permanent molar.	sensitivity & specificity=96.10
***Takahashi et al.,* 2020, [41]**	Japan	Yolov3	1282 panoramic radiograph	Employing DL method to identify dental implant systems	The mAP and mIoU of the proposed model were 0.71 and 0.72, respectively
***Leite et al.,* 2020, [42]**	Belgium	AI-tool	153 radiographs	Evaluating the performance of a model based on AI for tooth detection and segmentation	The suggested model achieved a sensitivity of <98% and a precision of <99%
***Vranckx et al.*,2020, [43]**	Belgium	CNN with Resnet-101	838 panoramic radiographs	Using DL to automatically segment mandibular molars on panoramic radiographs	The model achieved performance: precision=94% recall=93%
***Kök et al.,* 2020, [44]**	Türkiye	ANN	419 patients	The ANN was involved and trained on 24 datasets of cephalometric and hand-wrist radiographs to determine periods of growth and development in orthodontics.	High accuracy is obtained in training the model on the dataset, with the accuracy value reaching more than 94%.
***Lee et al.,* 2020, [45]**	South Korea	DCNNs	21,398 DIs in 7281 patients	The performance of three different DCNNs (VGGNet-19, GoogLeNet Inception-v3, and automated DCNN) architectures was evaluated for detecting and classifying dental implant fractures from panoramic and periapical radiographic images.	It was found that the automated DCNN had the most suitable performance, as it achieved the highest and most reliable detection (AUC = 0.984) and classification (AUC = 0.869).
***Bayrakdar et al.,* 2021, [46]**	Türkiye	DCNN	75 patients	Suggesting a deep learning model in implant planning using CBCT images.	The proper detection rate for the suggested model is 72.2% for canals, 66.4% for sinuses and fossa, & 95.3% for missing tooth areas.
***Ahn et al.,* 2021, [47]**	South Korea	ResNet-18, SqueezeNet, ResNet-101, & Inception-ResNet-V2	Patients database: 550 with mesiodens & 550 without mesiodens	Using DL models that automatically classify to detect primary or mixed teeth through panoramic	This work concluded that the most suitable performance of is the Inception-ResNet-V2 model,

				radiographs (JPEG format 2943 × 1435 pixels)	which achieved an accuracy exceeding 92%.
***Wang et al.*, 2021, [48]**	Netherlands	MS-DCNN	30 CBCT scans	Employing a MS-DCNN to perform multi-layer CT segmentation like binary segmentation in less time for the jaw, teeth, and background in CBCT scans.	The proposed model took about 25 seconds to scan the first part of CBCT, while the traditional segmentation method took about 5 hours. This model performed effects (Dice similarity coefficient: 0.934 ± 0.019, jaw; 0.945 ± 0.021, teeth).
***Kılıc et al.*, 2021, [49]**	Türkiye	Faster R-CNN (Inception v2)	421 panoramic images	Evaluating the performance of the Inception v2 model using a confusion matrix to detect and number deciduous teeth.	The proposed model was able to detect and number the deciduous teeth of children with a high-performance accuracy exceeding 98%.
***Kaya et al.*, 2022, [50]**	Türkiye	YOLO V4+ CNN	4545 pediatric panoramic X-ray images	Evaluating the performance of DL models in automatically detecting and numbering teeth on pediatric panoramic radiographs by training them on more than 4,500 images.	The proposed CNN method achieved high and fast performance for automated detection with an accuracy of more than 92%, a recall of 94.44%, and an F1-score of 91%.
***Çelik and Çelik*, 2022, [51]**	Türkiye	CNNs	684 objects in panoramic radiographs	Using a DL models to detect dental restorations	Faster R-CNN RegnetX is the most acceptable detection performance with mAP of 0.973 & AR of 0.771.
***Engels et al.*, 2022, [52]**	Germany	DCNN	1761 images	Developing and recognizing a DCNN for automated detection and categorizing posterior composite, cement, amalgam, gold and ceramic restorations on clinical photographs.	The CNN correctly classified the restorations with a diagnostic accuracy of more than 98%.
***Chen et al.*, 2022, [53]**	Taiwan	AlexNet, GoogLeNet, and SqueezeNet	108 panoramic X-rays	Using CNN architectures to detect dental diseases,	SqueezeNet model is the most acceptable performance for

				periodontitis, and restorations.	missing teeth with accuracy < 99%
***Kang et al.*,2022, [54]**	South Korea	RF, GBDT, SVM, LR, ANN, CNN, and LSTM	22,287 samples	Employing and training machine learning techniques to predict the risk of dental caries.	A comparison was completed between the techniques, and it was found that the most practical technique is RF, with an accuracy of 92%.
***Zhou et al.*, 2022, [55]**	China	CNN & CA-CNN	6028 teeth with 3039 caries images	Applying and improving the performance of CNNs for diagnosing children's dental caries on panoramic radiographs (210 patients with caries and 94 without caries)	Comparing performance through the accuracy metric: CNN=0.77.68% and CA-CNN=82.72%
***Tiryaki et al.*, 2023, [56]**	Türkiye	CNN	11904 images	Five deep CNN models were used to classify panoramic radiographs to accurately classify different dental implant brands and determine the angle of implant images.	All models were trained on the dataset, and their performance was measured. The most practical performance is the VGG-19 model, as it achieved an accuracy rate of over 98%.
***Zhang et al.*, 2023, [57]**	China	ResNet50	256 cephalometric radiographs	A deep prediction CNN was trained to determine the mandibular growth trend in children with anterior crossbite.	The proposed model achieves an accuracy of about 85% and focuses on special areas, including the chin, the lower edge of the mandible, incisor teeth, the airway and the condyle to conduct the prediction.
***Xu et al.*, 2023, [58]**	China	DL	6046 images	A method based on deep learning has been proposed to segment automatically and number teeth in panoramic radiographs. The dataset used in this study includes images of healthy and unhealthy teeth.	The suggested method based on deep learning earned precision and recall of 97% in teeth segmentation and numbering.
***Rubiu et al.*, 2023, [59]**	Italy	Mask-RCNN	1000 radiographs	Utilizing and training Mask-RCNN in performing accurate	The proposed strategy achieved excellent performance, as the

				teeth segmentation in panoramic dental X-rays.	percentage of correctly classified teeth reached more than 98%. This model is vital in determining the number of missing teeth.
***Ryu et al.*, 2023, [60]**	South Korea	Faster R-CNN	5000 panoramic radiographs	Using computer-assisted DL methods to accurately diagnose and detect periodontal diseases.	The AUC of the suggested method is 0.88 for detecting healthy and damaged teeth around the periodontally, and the AUC for the entire jaw, including edentulous regions, is 0.91.
***Chen et al.*, 2023, [61]**	Taiwan	YOLOv7	525 periapical X-ray images	Image processing and DL techniques have been applied to dental X-ray images to identify periodontitis and dental caries.	The suggested model achieved more than 97% precision in identifying periodontitis.
Total=30 Articles			2018=3, 2019=3, 2020=7, 2021=5, 2022=6, and 2023=6		

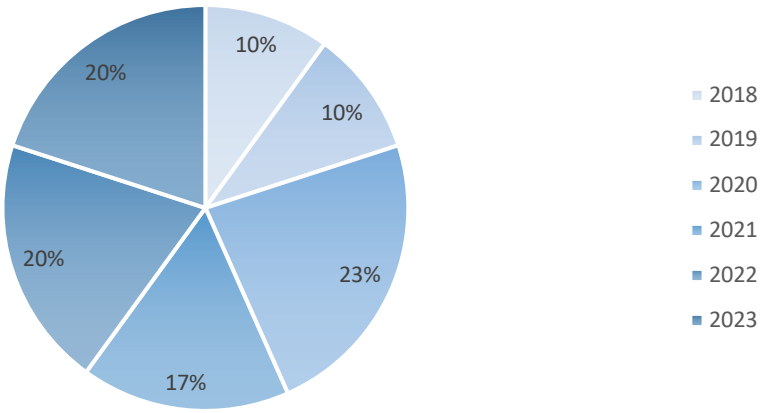

FIGURE 5. –Percentage of publications (selected articles) per year.

Table 2. - Number of publications (selected articles) by country.

Country=11	Total	Percentage
South Korea	8	27%
Türkiye	7	23%
China	4	14%
Germany	2	7%
Belgium	2	7%
Taiwan	2	7%
Switzerland	1	3%

Japan	1	3%
Italy	1	3%
Russia	1	3%
Netherlands	1	3%

Table 3. - Number of publications (selected articles) by journals.

Journals	Total	References
Journal of Dentistry	3	[33], [52], & [58]
Applied Sciences	3	[54], [59], & [60]
Dentomaxillofacial Radiology	3	[36], [49], & [51]
Scientific Reports	3	[32], [37], & [38]
Diagnostics	2	[45] & [47]
IEEE Access	2	[40] & [53]
The Journal of Advanced Prosthodontics	1	[34]
International Journal of Oral and Maxillofacial Surgery	1	[35]
Computational and Mathematical Methods in Medicine	1	[55]
The Journal of Prosthetic Dentistry	1	[56]
BMC Oral Health	1	[57]
Bioengineering	1	[61]
BMC Medical Imaging	1	[46]
Journal of Dental Research	1	[48]
Journal of Clinical Pediatric Dentistry	1	[50]
Acta Odontologica Scandinavica	1	[39]
International Journal of Implant Dentistry	1	[41]
Clinical Oral Investigations	1	[42]
International Journal of Environmental Research and Public Health	1	[43]
Orthodontics & Craniofacial Research	1	[44]
Total=20 journals	30 articles	

3. LEGAL AND ETHICAL CONSIDERATION

The ability of computers to perform tasks is considered better than humans, as it has been proven in many fields to the point that it has surpassed physicians' performance in explainability and data analysis. Artificial intelligence tasks have been developed in the early detection of diseases through automatic image recognition to detect disease patterns, analyze them, and make predictions. Integrating artificial intelligence techniques into health care is considered one of the essential things in developing the work environment of health institutions, and this leads to helping physicians and radiologists with the ability to analyze images and complex data with accuracy, high efficiency, and less time. Artificial intelligence generates the possibility of cooperation between humans and computers, which will facilitate some aspects of radiological work, and artificial intelligence will only partially replace radiologists. Artificial intelligence generates a set of recommendations through which physicians make the final decision on whether to act or not. Through this procedure, moral responsibility is securely maintained. The abilities possessed by artificial intelligence techniques are prediction, analysis of large amounts of data, process automation, and image recognition, as there are still doubts about the work of these techniques. Recent years have witnessed significant development and an apparent rise in the widespread use of applications supported by artificial intelligence and the growth of new methods that help accomplish substantial tasks [62-64]. Healthcare is one of the most important sectors in which we must be cautious with technological innovations because if something does not work well, patients' health may be at risk, or they may lose their lives. Therefore, healthcare workers should not be completely replaced, and there are no intelligent systems capable of displaying the full range of AI applications.

Automating the tasks humans perform in providing clinical care is yet to be possible, as the activities carried out by physicians and specialists still make treatment decisions based on a diagnosis that integrates data from laboratory tests, visual observation, and patient history. The computer has incredible computational power, speed, and accuracy, but it is clear that it does not replace the physician. Artificial intelligence practices do not possess human feelings, morals, or compassion. In addition, artificial intelligence is programmed by humans and works only as good as the data that humans provide it with. Therefore, there may be bias against a group of people, for illustration, people with disabilities or those who suffer from mental health problems. The outputs of artificial intelligence must be under continuous supervision. Medical errors cause significant harm, as they are considered one of the leading causes of death from cancer and heart disease in the United States [17] [65]. Artificial intelligence systems operate with programmed mechanisms according to

procedures unknown to everyone, and even their designers cannot fully know how these systems work inside. Physicians and health professionals must review the outputs of these systems and make an appropriate decision on whether to act based on the system's recommendations. In this way, ethical responsibility remains safely preserved because physicians decide to improve patient outcomes. The integration of artificial intelligence techniques in improving the field of dentistry generates many legal and ethical considerations, as healthcare workers are responsible for implementing these considerations to provide services that maintain the reputation of the health institution environment. Implementing artificial intelligence in clinical decision-making generates a set of essential considerations to consider and implement. Figure 6 shows the legal and ethical considerations for using artificial intelligence in the medical sector, especially dentistry.

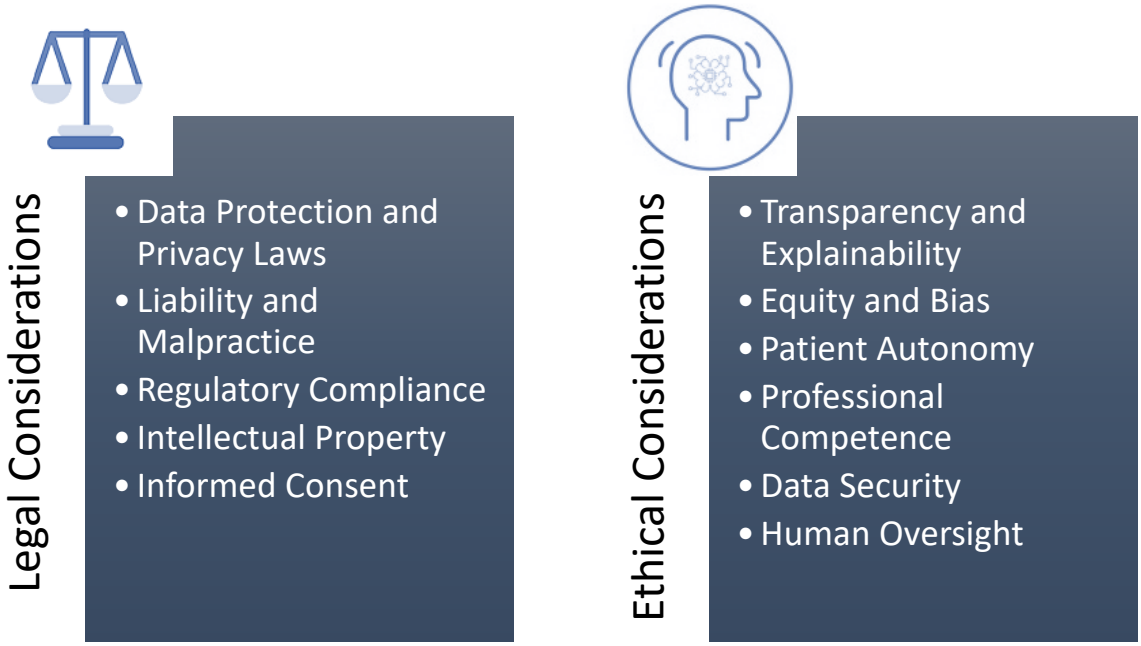

FIGURE 6. –Legal and Ethical Consideration of AI in healthcare.

In legal considerations, mechanisms must be implemented to protect patients' data and privacy by setting regulations that force all physicians, including dentists, to adhere to them. Dentists are committed to auditing the inputs and outputs of the systems they use and obtaining the patient's consent if he/she wants to send his information to another party for verification. Auditing the results generated by artificial intelligence is essential to avoid errors and preserve patients' health, as this procedure is considered one of the tasks of physicians and specialists. The design of applications and systems supported by artificial intelligence must be compatible with the field of medicine; that is, they must be compatible with dentistry, and they must first be reviewed and tested by authorized people to verify them and then employed in clinics and hospitals. Intellectual property rights are among the things that must be put in place to protect these systems to prevent use by unauthorized persons. Moreover, dentists must give patients full knowledge of the working mechanisms of the systems they use in their dental care and obtain their consent to apply them. In legal considerations, applications and systems supported by artificial intelligence must include transparency and explainability, as physicians must accept the medical decision-making process because it contains mechanisms for analyzing and treating diseases. Explainability is a critical matter that must be implemented in the design of artificial intelligence systems. Also, these systems must work correctly and fairly and not be biased toward a specific group of patients. Allow all patients to cancel all treatments or wearable devices, smartwatches, and mobile phone applications supported by artificial intelligence technologies and to inform physicians of their reports. This creates significant risks for initiatives seeking to make health data available in growing AI applications. Robust cybersecurity criteria must be in place to prevent access to protected health information by people who do not have the right to do so or have a need to know. All artificial intelligence techniques require training to use them, update them, and provide them with data. Activating human oversight of the performance of applications and systems in health institutions and monitoring them by qualified healthcare professionals to manage these systems. Ensuring the representation of human oversight would avoid representational bias and, therefore, increase social inequality and discrimination using these systems would be avoided.

4. CONCLUSIONS

Artificial intelligence techniques have been widely employed in dentistry in recent years, showing effects that assist dentists in enhancing patient care. Much literature has emerged showing that these techniques have performance accuracy equivalent to that of trained specialists. Moreover, these techniques have the advantage of overcoming human errors by

delivering outstanding results in diagnosing dental diseases and gum diseases. The results of the selected articles show that artificial intelligence techniques focus on dental caries, dental restoration, missing teeth, periodontal infections, planning, and treatment. The number of selected articles is 30 out of 432 from several databases where selection criteria were set. Only 7% of the articles were selected, and they are the most important articles in this field. These articles were published from 2018 to 2023, including three publications in 20218, three in 2019, seven in 2020, five in 2021, six in 2022, and six in 2023. South Korea tops the list of countries most interested in conducting articles on artificial intelligence in the field of dentistry, along with Türkiye. Besides, these articles concentrate primarily on seeking to integrate artificial intelligence applications in diagnosing disease conditions and allowing dentists to diagnose patients and take appropriate action quickly. Ultimately, most articles were shown to use convolutional neural networks, as they have the ability to learn based on the training they undergo and are error tolerant.

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CONFLICTS OF INTEREST

The author declares no conflict of interest.

NOMENCLATURES

Acronym	Description
AI	Artificial intelligence
ANN	Artificial neural network
AUC	Area under the ROC Curve
CA-CNN	Context aware convolutional neural network
CAD	Computer-aided design
CBCT	Cone beam computed tomography
CNN	Convolutional neural networks
DCNN	Deep convolutional neural networks
DL	Deep learning
DT	Decision tree
Faster R-CNN	Faster region-based convolutional neural network
GBDT	Gradient-boosted decision trees
JPEG	Joint Photographic Experts Group
LR	Logistic Regression
LSTM	Long short-term memory networks
Mask-RCNN	Mask- region-based convolutional neural network
MeSH	Medical Subject Headings
ML	Machine learning
MS-DCNN	Multi-scale deep convolutional neural network
NLP	Natural language processing
PBL	Periodontal bone loss
ResNet-FPN	Residual network-Feature pyramid network
RF	Random forest
SVM	Support vector machine
VGG16	Visual Geometry Group, is a CNN that is 16 layers deep.
VGGNet-19	Visual Geometry Group, is a CNN that is 19 layers deep.
Yolov3	You Only Look Once, Version 3

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