Journal of Dentomaxillofacial Radiology, Pathology and Surgery
Spring 2025, Volume 14, Number 2

Review Paper: Emerging Applications of Artificial Intelligence in Modern Dentistry: Advancements, Challenges, and Future Directions

Moein Hoseini Shirazi[1*], Foroozan Farahbod[1], Mohammed Hussein Alsharbaty[2]

1. *School of Dentistry, University of Copenhagen, Copenhagen, Denmark*
2. *College of Dentistry, University of Al-Ameed, Karbala, Iraq*

Use your device to scan and read the article online

Citation Hoseini Shirazi M, Farahbod F, Alsharbaty MH. Emerging Applications of Artificial Intelligence in Modern Dentistry: Advancements, Challenges, and Future Directions. Journal of Dentomaxillofacial Radiology, Pathology and Surgery. 2025; 14(2): 1-6

https://doi.org/10.22034/3DJ.14.2.1

Article info:
Received: 18 Mar 2025
Accepted: 20 Apr 2025
Available Online: 28 Apr 2025

Keywords:
*Artificial Intelligence
*Deep Learning
*Dentistry
*Medical Informatics

ABSTRACT

The integration of artificial intelligence (AI) into modern dentistry is a transformative advancement with significant implications. Emerging in the mid-20th century, AI has evolved through the development of neural networks that mimic the structure of the human brain. A key subset, deep learning, has revolutionized diagnostics and therapies across various medical disciplines by enabling autonomous data processing. In dentistry, AI's widespread adoption is driven by technological progress and digitization, leading to improvements in dental diagnostics. Computer-generated second opinions enhance the accuracy and efficiency of diagnoses, particularly in dental radiology, where neural networks expedite the process. Beyond radiology, neural networks are utilized in various specialties, such as restorative dentistry for caries detection and restoration selection, endodontics for periapical lesion detection and treatment prediction, orthodontics for diagnosis and treatment planning, and dental surgery for complication prediction. Additionally, AI contributes to periodontal evaluation and prediction based on psychological factors. Despite its advantages, the integration of AI in dentistry requires further research to ensure seamless adoption and reduce the risk of errors. Combining AI with traditional methods is recommended to minimize discrepancies in outcomes, and collaboration between clinicians, researchers, and engineers is essential for the successful development and implementation of AI, ultimately advancing dental practice while prioritizing patient care.

1. Introduction

In contemporary healthcare, the integration of artificial intelligence (AI) is revolutionizing medical and dental practices. Originating in 1943, AI gained prominence with the term coined by John McCarthy at a Dartmouth conference in 1956. Subsequently, subsets like machine learning, neural networks, and deep learning have emerged, driving advancements in predictive analytics and problem-solving (1).

Neural networks, modeled after the human brain's neural structure, are pivotal in AI's evolution. They comprise layers—input, hidden, and output—that process data to yield desired outcomes. Multilayer perceptron (MLP) neural networks, featuring additional hidden layers, offer enhanced complexity. Common neural network types include artificial neural networks (ANN), convolutional neural networks (CNN), and recurrent neural networks (2).

Deep learning, a subset of neural networks, enables autonomous data processing. With thousands to millions of neurons in the hidden layer, deep learning fosters intricate computations. AI's applications extend across medical disciplines like radiology, pathology, oncology, cardiology, psychiatry, and nuclear medicine, augmenting diagnostics, therapies, and cost reduction efforts. Moreover, neural network models serve as valuable tools for comprehending intricate nervous system functions, unattainable through conventional research methods (3).

In dentistry, AI's proliferation is fueled by technological advancements and digitization. Dental diagnostics benefit from computer-generated second opinions, enhancing accuracy and efficiency. Neural networks expedite diagnosis processes, prompting a surge in

*** Corresponding Authors:**
Moein Hoseini Shirazi
Address: *School of Dentistry, University of Copenhagen, Copenhagen, Denmark*
E-mail: *moein.hshirazi@gmail.com*

research and development efforts (4).

The emergence of artificial intelligence (AI) in healthcare has opened doors to significant advancements. AI's capacity to train computer programs for intelligent tasks holds promise for enhancing patient care and diagnostic accuracy, thereby minimizing errors in clinical practice. From expert systems to atlas-based models and now deep learning, medical image interpretation has evolved, leveraging vast digital radiograph datasets to revolutionize radiology diagnostics (2).

Deep learning, coupled with AI, offers potential for automated data mining, paving the way for new discoveries with minimal human intervention. Wearable technologies equipped with intelligent applications can forecast impending health crises like strokes, enabling timely interventions by healthcare providers (3). Additionally, AI facilitates efficient analysis of electronic medical records and scientific databases, enhancing the diagnosis of congenital anomalies and aiding in medical research (1).

Machine learning techniques such as support vector machines (SVM) have become indispensable in medical analysis, enabling the classification of complex conditions like traumatic brain injury. In cardiovascular medicine, where precision is paramount, deep learning holds promise for accurate disease identification and treatment optimization. Furthermore, AI-driven analysis of viral surveillance data contributes to translational research, filling knowledge gaps and improving cost-effectiveness (4).

In disease management, AI serves as a potent tool for analyzing treatment outcomes and developing precision medicine approaches. Machine learning algorithms demonstrate promise in predicting therapeutic responses, as evidenced by meta-analyses achieving an overall accuracy of 82% in depression treatment prognosis (5). Moreover, in ophthalmology, AI shows potential for enhancing diagnoses and treatment strategies for various eye conditions, including corneal ectasias, glaucoma, age-related macular degeneration, and diabetic retinopathy (6).

Artificial intelligence, particularly neural networks, holds promise for various clinical applications in restorative dentistry. In diagnosis and treatment planning, neural networks offer valuable assistance, particularly in the analysis of dental X-rays for caries and restoration detection. Beyond radiology, neural networks show potential in fields like microbiology, aiding in treatment decision-making for optimal patient care (4).

Early detection of dental caries, the most prevalent dental disease, is imperative for effective treatment. Traditional methods, such as dental probes and visual observation, though subjective, remain commonly employed by dentists. However, these methods may prove inadequate, particularly for detecting caries on approximal surfaces (1). Modern dentistry relies on additional diagnostic tools like radiographs, including bitewings, periapical X-rays, and panoramic X-rays, to supplement clinical assessments. While cone-beam computed tomography (CBCT) is less frequently used for caries detection, it can offer valuable insights (7).

Neural networks have emerged as promising aids in dental caries detection on radiological images, offering speed and precision. Although neural network utilization in conservative dentistry is still evolving, recent studies indicate promising outcomes. Algorithms equipped with neural networks can effectively differentiate anatomical and pathological structures, even amidst image noise and low contrast (7). For instance, Geetha et al. demonstrated the efficacy of an artificial neural network in detecting caries on radiographs with an impressive accuracy of 97.1% and a low false positive rate of 2.8% (8).

Furthermore, artificial intelligence shows potential in detecting and classifying dental restorations. Research by Abdalla-Aslan et al. showcased algorithms capable of identifying 93.6% of dental restorations on panoramic images, categorizing them into 11 distinct types based on shape and grey value distribution (9).

Neural networks also aid in treatment planning and cavity preparation techniques selection. Javed et al. utilized artificial neural networks to predict post-Streptococcus mutans levels before dental caries excavation, aiding in personalized treatment planning. Their study, conducted on 45 primary molars, achieved an impressive accuracy of 99.03%, minimizing the need for post-treatment examinations, re-excavations, and associated pulpal trauma (10).

Further research is warranted to integrate these technologies into routine clinical practice. Additionally, other aspects of restorative dentistry could benefit from neural networks, expanding their role in decision-making processes across various domains within the field showed that not only the inflammation, but also other biological processes may individuate.

The application of artificial intelligence is gaining significance in endodontics, offering valuable contributions to various aspects of clinical practice. From detecting periapical lesions and root fractures to evaluating root canal anatomy and predicting treatment outcomes, artificial intelligence shows promise in enhancing diagnostic accuracy and treatment planning.

Artificial neural networks serve as decision-making systems for precise localization of minor apical foramen on radiographs. In a study by Saghiri et al., the use of artificial neural networks resulted in significantly higher accuracy (96%) compared to human assessments (76%) in determining canal lengths, highlighting their potential for precise localization of apical foramen (11).

Apical periodontitis, primarily caused by bacterial infection of the root canal system, is commonly detected through radiographic diagnostics, presenting as periapical translucencies or lesions. Deep learning techniques, such as convolutional neural networks (CNN), have shown promise in detecting periapical lesions on cone-beam computed tomographic (CBCT) images. Setzer et al. achieved an impressive 93% accuracy in lesion detection using deep learning on CBCT images (12), while Orhan et al. reported 92.8% accuracy with CNN, comparable to experienced dental practitioners' assessments (13).

Moreover, CNNs have been employed to evaluate periapical radiographs for lesion detection with remarkable accuracy. Pauwels et al. reported a perfect accuracy of 87% in detecting periapical lesions using CNN, demonstrating its potential for precise radiographic analysis (14). However, challenges remain in assessing panoramic images for periapical lesions, particularly in differentiating tooth types due to variability in radiographic image generation. Ekert et al. noted varying sensitivities and specificities in detecting periapical lesions on panoramic images, emphasizing the need for improved diagnostic sensitivity, especially in molars (15).

Artificial neural networks extend beyond dental radiology into genetics, offering insights into the biological processes underlying conditions like radicular cysts (RCs) and periapical granulomas (PGs). In Poswar et al.'s study, artificial intelligence analysis of gene expression patterns highlighted distinct biological processes associated with RCs and PGs, underscoring the potential of AI in elucidating disease mechanisms (16).

In the field of endodontics, neural networks show promise, particularly in X-ray analysis and the identification of periapical lesions. Further enhancements are needed to ensure accurate detection across all teeth. Additionally, artificial intelligence holds potential beyond radiological applications, including genetic analysis, offering opportunities to streamline diagnosis processes in various domains.

Artificial intelligence is becoming increasingly prevalent in orthodontics, with various algorithms being utilized, including artificial neural networks (ANN), convolutional neural networks (CNN), support vector machines, and regression algorithms. Peilini et al. employed an ANN in their study to predict the necessity of extractions in patients' treatment plans, taking anchorage patterns into account. They achieved 94.0% accuracy for extractions and 92.8% for predicting maximum anchorage use, suggesting ANN's potential to enhance precision in treatment planning for orthodontists (17).

Auconi et al. devised a system based on artificial neural networks to forecast treatment outcomes in class II and III patients, anticipating auxological anomalies during craniofacial growth and identifying potential sites for therapeutic interventions in malocclusion (18). Furthermore, deep learning neural networks have shown promise in detecting temporomandibular joint (TMJ) osteoarthritis, a prevalent musculoskeletal condition. Bianchi et al. conducted research utilizing TMJ CBCT scans, serum, and saliva tests to diagnose TMJ impairment before morphological degeneration occurs (19).

In another study by Muraev et al., ANN demonstrated comparable accuracy to experienced dentists in placing cephalometric points on radiographs and, in some cases, even surpassed new doctors in precision (20). Additionally, ANN has been employed by Kök et al. to determine growth and development periods using cephalometric and hand-wrist radiographs, achieving an accuracy rate of 94.27% (21).

Overall, neural networks find application in various aspects of orthodontics, including diagnosis, treatment planning, anatomic analysis automation, growth and development assessment, and treatment outcome evaluation. The integration of artificial intelligence in orthodontics holds significant potential for further expansion and refinement.

According to research findings, neural networks hold significant potential for widespread application in dental surgery. For instance, Chien-Hsun Lu et al. conducted a study aimed at enhancing post-orthognathic surgery image predictions for individual patients, potentially benefiting surgeons, orthodontists, and patients by refining treatment plans (22). Similarly, Patcas et al. utilized artificial intelligence to assess the impact of orthognathic surgery on facial attractiveness and age appearance, with convolutional neural networks analyzing pre- and post-treatment photographs to estimate age and attractiveness changes (23). Byung Kim et al. employed convolutional neural networks to predict the likelihood of paresthesia of the inferior alveolar nerve following third molar extraction, a common dental procedure. However, they noted limitations in using two-dimensional panoramic radiographs for accurate prediction (24).

In odontogenic lesion detection, Liu et al. demonstrated the efficacy of deep learning, specifically convolutional neural networks, in identifying ameloblastoma and odontogenic keratocyst in panoramic radiographs. This approach, leveraging transfer learning algorithms, showcased promising accuracy rates, aiding oral maxillofacial specialists in pre-surgical assessment (25).

Moreover, neural networks offer potential applications in implantology, facilitating treatment planning using three-dimensional cone-beam computed tomography (CBCT) images and identifying implant brands and treatment stages on panoramic radiographs (26). Additionally, convolutional neural networks can assess osteointegration quality, potentially detecting complications such as soft tissue layer presence around the bone-implant interface (26).

Overall, neural networks are poised to revolutionize various aspects of dental surgery, ranging from orthognathic surgeries to implantology. Particularly in implantology, where precision and meticulous planning are paramount, neural networks offer valuable support in predicting and potentially mitigating surgical complications.

Periodontitis is a prevalent disease affecting billions worldwide, potentially leading to tooth mobility and loss if left untreated. Early detection and effective therapy are essential to prevent such outcomes. Current diagnostic methods, including dental probing and radiographic evaluation, are susceptible to examiner variability. To enhance diagnostic accuracy, researchers have turned to neural networks.

For instance, Krois et al. utilized convolutional neural networks to assess panoramic radiographs for periodontal bone loss, achieving higher accuracy (83%) compared to experienced dentists (80%) (27). Similarly, Cha et al. employed convolutional neural networks to detect peri-implant bone loss on dental periapical radiographs, offering a method to evaluate peri-implantitis severity (28).

In another study, Lee et al. utilized a deep convolutional neural network to analyze radiographs and measure radiographic bone loss for each tooth, demonstrating an accuracy of 85%. This suggests that neural networks can serve as valuable tools for assessing radiographic bone loss and obtaining image-based periodontal diagnoses (29).

Furthermore, researchers like Chang et al. have developed automatic methods for staging periodontitis using neural networks on panoramic images, detecting periodontal bone levels and teeth positions (30).

The integration of neural networks into periodontology holds promise for clinicians and researchers alike, offering precise bone loss assessment crucial for diagnosis and treatment planning. However, further research and refinement are necessary to effectively integrate this technology into routine periodontal practice.

In the realm of dentistry, the integration of artificial intelligence (AI) continues to grow, driven by the demand for precision and efficient information exchange. With AI's ongoing advancements, its impact on dentistry is expected to be profound and imminent. Machine learning, particularly deep learning, holds promise in enhancing understanding of complex oral diseases and conditions that remain poorly understood.

In the foreseeable future, dental clinics may adopt an AI-Comprehensive Care System, where AI tools play pivotal roles at every stage of patient care. Before each appointment, an AI patient history analyzer would assess the planned treatment, considering factors such as patient demographics, vital signs, medical history, and dental records.During the appointment, AI-driven diagnostics would aid clinicians in formulating accurate diagnoses and treatment recommendations, considering critical medical concerns and providing real-time feedback to minimize errors (4).

Technological advancements, such as computer-aided design/computer-assisted manufacture (CAD/CAM), are anticipated to integrate AI capabilities into dental prosthetic design processes. AI-driven software would facilitate the design of prostheses with optimal aesthetics and functionality, enhancing precision and minimizing failure risks. Similarly, in dental implant therapy, AI would streamline treatment planning by automating tasks such as merging CBCT and intraoral scan data, designing restorations, and guiding surgical procedures (4,5).

Moreover, AI offers opportunities for dental institutes and clinics to leverage big data for training AI systems and improving prognostic predictions (2). Hands-on training can be enhanced through unbiased assessment using AI tools, contributing to more objective feedback and better learning outcomes for dental students (1). Additionally, AI-based services are poised to revolutionize various aspects of dental practice management, from decision-making based on radiographic and intraoral scan data to improving patient experiences through personalized preferences (4,5).

Furthermore, AI is expected to play a significant role in dental insurance processes, enabling immediate claim approvals based on uploaded diagnostic data. This streamlined process would enhance transparency and expedite patient access to dental care (3).

Beyond clinical applications, AI-driven enhancements to the dental patient experience are anticipated, with AI learning and accommodating patient preferences for appointment scheduling, environmental factors, and entertainment choices. By improving patient satisfaction and access to care, AI stands to promote better oral and systemic health outcomes (1,2).

While AI presents promising opportunities for dentistry, practitioners must maintain a fundamental understanding of AI principles and limitations to make informed decisions about its integration into dental practice. As AI technologies continue to evolve, their potential to revolutionize dental care and patient experiences is considerable.

Utilizing AI to address complex problems necessitates comprehensive algorithms capable of addressing multifaceted inquiries. However, akin to data mining, AI often yields results based on associations rather than causality, lacking direct interpretation. Collaborative efforts involving experienced clinicians and expert computer engineers are essential to mitigate potential algorithmic misconceptions and ensure AI's safe and effective use (31). Despite its potential, recent issues with AI applications, such as those encountered with IBM Watson, underscore the need for ongoing refinement and enhancement in healthcare settings.

Moreover, the increasing reliance on AI for diagnostics raises liability concerns, emphasizing the importance of clinicians maintaining vigilance and critical judgment in interpreting AI-generated information. Compliance with regulations such as the Health Insurance Portability and Accountability Act (HIPAA) is paramount to safeguarding patient medical information, particularly concerning the exchange and application of training data sets. Adherence to HIPAA regulations must be upheld diligently to prevent any breaches or violations during the training and utilization of AI models (32).

2. Conclusions

Dentistry is rapidly evolving with the advent of new technologies, particularly artificial intelligence (AI) and neural networks, which are revolutionizing various aspects of dental practice. Primarily employed in dental radiology, these technologies aid in diagnosis, treatment planning, and prognostication of treatment outcomes. Beyond radiology, neural networks find applications in diverse dental specialties such as restorative dentistry, endodontics, orthodontics, dental surgery, and periodontology.

In restorative dentistry, neural networks play a crucial role in detecting tooth decay, facilitating caries excavation methods, and assisting in restoration selection. Similarly, in endodontics, these technologies contribute to periapical lesion detection, root canal anatomy evaluation, and predicting treatment success rates. Orthodontics benefits from neural networks in diagnosis, treatment planning, cephalometric analysis, and growth assessment. In dental surgery, neural networks aid in orthognathic surgery planning, post-extraction complication prediction, bone lesion detection, and implantological treatment planning.

Moreover, AI is making inroads into periodontology, enabling evaluation of periodontal and peri-implant bone loss and predicting periodontitis development based on psychological features. While AI offers numerous benefits such as enhanced efficiency, accuracy, and time-saving, its integration into dentistry necessitates further research to ensure seamless adoption into daily practice.

The expanding role of AI in dentistry is poised to benefit clinicians and researchers by amalgamating diverse fields of knowledge and enhancing patient care. However, cautious interpretation of AI-generated data is imperative to mitigate potential errors. Combining AI technology with conventional methodologies is deemed prudent to minimize output discrepancies. The authors advocate for inter-professional collaboration among clinicians, researchers, and engineers to foster the development and integration of AI in dentistry. Through such collaborative efforts, AI stands to revolutionize dental practice while ensuring patient welfare remains paramount.

Ethical Considerations

This study is a review article, and ethical considerations are not applicable.

Funding

No external funding was received for this study.

Authors' Contributions

Moein Hoseini Shirazi: Conceptualization, Methodology, Writing – Original Draft, Writing – Review & Editing, Supervision **Foroozan Farahbod:** Conceptualization, Methodology, Investigation, Data Curation **Mohammed Hussein Alsharbaty:** Conceptualization, Methodology, Investigation, Resources.

Conflict of Interests

The authors declare no conflicts of interest.

Availability of Data and Material

Not applicable.

Acknowledgements

None.

References

1. Ossowska A, Kusiak A, Świetlik D. Artificial intelligence in dentistry—Narrative review. Int J Environ Res Public Health. 2022;19(6):3449. [DOI: 10.3390/ijerph19063449] [PMID] [PMCID]
2. Chen YW, Stanley K, Att W. Artificial intelligence in dentistry: current applications and future perspectives. Quintessence Int. 2020;51(3):248-57. [DOI:10.3290/j.qi.a43952] [PMID]
3. Schwendicke F, Samek W, Krois J. Artificial intelligence in dentistry: chances and challenges. J Dent Res. 2020;99(7):769-74. [DOI: 10.1177/0022034520915714] [PMID] [PMCID]
4. Agrawal P, Nikhade P, Nikhade PP. Artificial intelligence in dentistry: past, present, and future. Cureus. 2022;14(7). [DOI: 10.7759/cureus.27405] [PMID] [PMCID]
5. Jiang F, et al. Artificial intelligence in healthcare: past, present and future. Stroke Vasc Neurol. 2017;2(4):230-43. [DOI: 10.1136/svn-2017-000101] [PMID] [PMCID]
6. Hogarty DT, Mackey DA, Hewitt AW. Current state and future prospects of artificial intelligence in ophthalmology: a review. Clin Exp Ophthalmol. 2019;47(1):128-39. [DOI: 10.1111/ceo.13381] [PMID]
7. Hosny A, et al. Artificial intelligence in radiology. Nat Rev Cancer. 2018;18(8):500-10. [DOI: 10.1038/s41568-018-0016-5] [PMID] [PMCID]8. Khanagar SB, et al. Application and performance of artificial intelligence technology in detection, diagnosis and prediction of dental caries (DC)—a systematic review. Diagnostics. 2022;12(5):1083. [DOI: 10.3390/diagnostics12051083] [PMID] [PMCID]
8. Stafie CS, et al. Exploring the intersection of artificial intelligence and clinical healthcare: a multidisciplinary review. Diagnostics. 2023;13(12):1995. [DOI: 10.3390/diagnostics13121995] [PMID] [PMCID]
9. Javed S, et al. Development of artificial neural network model for prediction of post-streptococcus mutans in dental caries. Comput Methods Programs Biomed. 2020;186:105198. [DOI: 10.1016/j.cmpb.2019.105198] [PMID]
10. Saghiri MA, et al. The reliability of artificial neural network in locating minor apical foramen: a cadaver study. J Endod. 2012;38(8):1130-4. [DOI: 10.1016/j.joen.2012.05.004] [PMID]
11. Setzer FC, et al. Artificial intelligence for the computer-aided detection of periapical lesions in cone-beam computed tomographic images. J Endod. 2020;46(7):987-93. [DOI:

10.1016/j.joen.2020.03.025] [PMID]
12. Orhan KAA, et al. Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans. Int Endod J. 2020;53(5):680-9. [DOI: 10.1111/iej.13265] [PMID]
13. Pauwels R, et al. Artificial intelligence for detection of periapical lesions on intraoral radiographs: Comparison between convolutional neural networks and human observers. Oral Surg Oral Med Oral Pathol Oral Radiol. 2021;131(5):610-6. [DOI: 10.1016/j.oooo.2021.01.018] [PMID]
14. Ekert T, et al. Deep learning for the radiographic detection of apical lesions. J Endod. 2019;45(7):917-22. [DOI: 10.1016/j.joen.2019.03.016] [PMID]
15. de Oliveira Poswar F, et al. Bioinformatics, interaction network analysis, and neural networks to characterize gene expression of radicular cyst and periapical granuloma. J Endod. 2015;41(6):877-83. [DOI: 10.1016/j.joen.2015.02.004] [PMID]
16. Li P, et al. Orthodontic treatment planning based on artificial neural networks. Sci Rep. 2019;9(1):2037. [DOI: 10.1038/s41598-018-38439-w] [PMID] [PMCID]
17. Auconi P, et al. A network approach to orthodontic diagnosis. Orthod Craniofac Res. 2011;14(4):189-97. [DOI: 10.1111/j.1601-6343.2011.01523.x] [PMID]
18. Bianchi J, et al. Osteoarthritis of the temporomandibular joint can be diagnosed earlier using biomarkers and machine learning. Sci Rep. 2020;10(1):8012. [DOI: 10.1038/s41598-020-64942-0] [PMID] [PMCID]
19. Muraev AA, et al. Frontal cephalometric landmarking: humans vs artificial neural networks. Int J Comput Dent. 2020;23(2). [PMID]
20. Kök H, Izgi MS, Acilar AM. Determination of growth and development periods in orthodontics with artificial neural network. Orthod Craniofac Res. 2021;24:76-83. [DOI:10.1111/ocr.12443] [PMID]
21. Lu CH, Ko EW-C, Liu L. Improving the video imaging prediction of postsurgical facial profiles with an artificial neural network. J Dent Sci. 2009;4(3):118-29. [DOI: 10.1016/S1991-7902(09)60017-9]
22. Patcas R, et al. Applying artificial intelligence to assess the impact of orthognathic treatment on facial attractiveness and estimated age. Int J Oral Maxillofac Surg. 2019;48(1):77-83. [DOI: 10.1016/j.ijom.2018.07.010] [PMID]
23. Kim BS, et al. Deep learning-based prediction of paresthesia after third molar extraction: A preliminary study. Diagnostics. 2021;11(9):1572. [DOI: 10.3390/diagnostics11091572] [PMID] [PMCID]
24. Liu Z, et al. Differential diagnosis of ameloblastoma and odontogenic keratocyst by machine learning of panoramic radiographs. Int J Comput Assist Radiol Surg. 2021;16:415-22. [DOI: 10.1007/s11548-021-02309-0] [PMID] [PMCID]
25. Kang DY, Duong HP, Park JC. Application of deep learning in dentistry and implantology. J Implantol Appl Sci. 2020;24(3):148-81. [DOI: 10.32542/implantology.202015]
26. Krois J, et al. Deep learning for the radiographic detection of periodontal bone loss. Sci Rep. 2019;9(1):8495. [DOI: 10.1038/s41598-019-44839-3] [PMID] [PMCID]
27. Cha JY, et al. Peri-implant bone loss measurement using a region-based convolutional neural network on dental periapical radiographs. J Clin Med. 2021;10(5):1009. [DOI: 10.3390/jcm10051009] [PMID] [PMCID]
28. Lee JH, et al. Diagnosis and prediction of periodontally compromised teeth using a deep learning-based convolutional neural network algorithm. J Periodontal Implant Sci. 2018;48(2):114-23. [DOI: 10.5051/jpis.2018.48.2.114] [PMID] [PMCID]
29. Chang HJ, et al. Deep learning hybrid method to automatically diagnose periodontal bone loss and stage periodontitis. Sci Rep. 2020;10(1):7531. [DOI: 10.1038/s41598-020-64509-z] [PMID] [PMCID]
30. Pethani F. Promises and perils of artificial intelligence in dentistry. Aust Dent J. 2021;66(2):124-35. [DOI: 10.1111/adj.12812] [PMID]
31. Mörch CM, et al. Artificial intelligence and ethics in dentistry: a scoping review. J Dent Res. 2021;100(13):1452-60. [DOI: 10.1177/00220345211013808] [PMID]