

# ARTIFICIAL INTELLIGENCE AIDING IN THE PERIODONTAL ASSESSMENT

An Undergraduate Research Scholars Thesis

by

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This project did not require approval from the Texas A&M University Research Compliance & Biosafety office.

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# **ABSTRACT**

Artificial Intelligence Aiding in the Periodontal Assessment

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While manual probing is the gold standard for periodontal assessments, it can be time consuming. Patients can be wrongfully classified due to an inconsistency between examiners, the amount of time a clinician is given for an appointment, and human error. Artificial intelligence (AI) is implemented in other areas of healthcare, known as precision healthcare. A type of AI, convolutional neural networks (CNN), identifies portions of images with the use of an algorithm to identify the image. Radiographs are a vital part of the periodontal classification system. These images are read with the human eye, there is room for human error. CNN can aid the clinician in reading and identifying images to speed up this process, allotting more time in the appointment for services such as the cleaning and patient education. AI is currently being used in the dental field for the detection of pathology, dental charting, caries, plaque, and periodontitis using 2D and 3D imaging. CNN is showing promising results in dentistry by having the capability of

interpreting radiographs using an algorithm to aid in the various classifications. Limitations of AI and CNN in the periodontal field include the need for further testing of this technology with 2D and 3D radiographs, protecting the patient's confidentiality, and further exploration of the cost to integrate this system into a dental practice. While the use of AI and CNN technology may not replace the gold standard of periodontal assessment, it has the potential to aid clinicians in more effective and individualized patient care.

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## NOMENCLATURE

|      |                                |
|------|--------------------------------|
| AI   | Artificial Intelligence        |
| CNN  | Convolutional Neural Networks  |
| ANI  | Artificial Narrow Intelligence |
| RBL  | Radiographic Bone Loss         |
| FDA  | Food and Drug Administration   |
| SaMD | Software as Medical Device     |
| CBCT | Cone-beam Compound Tomography  |

## INTRODUCTION

A study was conducted in the emergence of COVID-19 with artificial intelligence (AI) using deep convolutional neural networks (CNN) in diagnosing patients with COVID-19.<sup>1</sup> Lung tomography scans were used to distinguish between COVID-19 positive and COVID-19 negative patients. This was a clinical study using 10,153 CT scans.<sup>1</sup> Diagnosis via CNN could aid healthcare providers in an earlier detection of COVID-19, thus treatment begins earlier, and patients possibly have a better recovery.

The study yielded a 0.999, 0.986, and 0.996 accuracy rate in differentiating between COVID-19 positive and negative patients.<sup>1</sup> This is important because it shows the integration of AI in diagnostics can make the process more efficient and increase patient acceptance more than the conventional approach. As computer processing capabilities become more innovative and inexpensive, AI could offer earlier diagnosis and treatment in all aspects of healthcare.

Evidence suggests that implementation of AI into the United States healthcare system could create \$150 billion savings annually.<sup>2</sup> The belief is that implementation of AI into the healthcare system could alter the current treatment-based healthcare system into a prevention-based system.<sup>3</sup> This also suggests that AI could be implemented more into our society and become a societal norm.

AI is used in healthcare diagnostics, like in the diagnosis of COVID-19. AI is also used in a variety of areas of dentistry such as radiology, periodontics, oral pathology, orthodontics, and endodontics.<sup>4</sup> The purpose of this research is to further investigate the use of AI in oral health care during the periodontal assessment, thus improving the validity, reliability, and efficiency in making a proper periodontal diagnosis. Research on this subject aligns with the current NDHRA



in the category of Basic Science: Clinical decision support tools. The intent of this narrative review is not to call for the replacement of clinicians with the use of AI, but to bring awareness of the use of AI as an assistant in periodontal assessment to allow for earlier and more accurate diagnosis. AI can also aid in the clinician's patient management making it more efficient and effective. This research will assess AI in the context of precision healthcare, merits and limitations of tools used in periodontal assessment, and the potential integration of AI in the dental hygiene process of care.

# **1. DEFINE ARTIFICIAL INTELLIGENCE IN THE CONTEXT OF PRECISION HEALTHCARE**

AI is a broad subdivision of computer science that has the ability to perform a correct interpretation of external data, learns from that data, and uses what it learns to achieve specific goals and tasks through versatile adaptation.<sup>5</sup> AI works by processing large amounts of data and analyzing that data for correlations and patterns of interest.<sup>5</sup> In the 14th century, Ramon Llull's book reflected the idea of a mechanical invention that would imitate human logic.<sup>5</sup> Then, in the 1950s Alan Turing established the conception of universal computer and AI used today.<sup>5</sup> AI is used in daily life such as voice or image recognition used in cellphones, navigation systems, etc. AI has evolved and developed more in recent years, for instance, AI is utilized in the medical field for surgical procedures.<sup>5</sup> Consequently, the use of AI is becoming a subject of interest in the dental field by working on incorporating AI as a diagnostic aid in oral pathology, radiology for diagnosis of caries and classification of periodontal disease, endodontics, and other specialties.<sup>5</sup>

Currently, Artificial Narrow intelligence (ANI) is in a stage that involves machines that can perform only a defined set of tasks that depend on human instruction.<sup>4</sup> CNN is a deep learning neural network that has developed exponentially since 2010.<sup>5</sup> CNN is designed to process structured arrays of large amounts of data like images.<sup>5</sup> It is widely used in computer vision.<sup>5</sup> CNN is a network of nodes that can identify images. Each node of the network is tasked with examining a portion of the image and converting its findings into numerical values.<sup>2</sup> These values can be used to identify patterns in the image to determine what the image is.<sup>2</sup>

To aid the process of periodontal assessment, it may be necessary to consider the incorporation of advanced visual recognition and deep learning techniques, such as CNN that

will allow for identification of the extent of bone resorption. The use of AI would allow the clinicians to efficiently and precisely determine bone loss based on images in a dataset.<sup>4,6</sup> CNN works in a manner that makes a prediction using the radiographic images of the patient by comparing those images to a dataset of known cases where bone loss has been previously determined.<sup>4,6</sup> A relatively recent interdisciplinary field, known as bioinformatics, combines biological and computer sciences and is being used to analyze complex biological data with the aim of achieving precision dental medicine. The principle of Precision medicine was approached by The American Academy of Sciences, the American Academy of Engineering, the National Institutes of Health, and the American Science Council conjointly issued the initiative “Towards Precision Medicine” in 2011.<sup>8</sup> The aim of this initiative was to create a new taxonomy of disease classification to provide a more personalized diagnosis and treatment according to the individual characteristics of patients.<sup>8</sup> The 4P medicine is an acronym that encompasses the vision of medicine as predictive, preventive, personalized, and participatory.<sup>7,8</sup> Before the rise of precision medicine came about, traditional or conventional medicine was initially empirically-based because it was focused on treating signs and symptoms of a disease.<sup>7,8</sup> Eventually, intuition medicine evolved into what is currently known as Evidence-based-medicine which is found on scientific research such as clinical trials.<sup>7</sup> It is more generalized and cannot address outliers adequately.<sup>7</sup> As a result, health sciences are in a transition period since precision medicine is seen as the medicine of the future that will be based on data collected from the patient’s information and the so call “OMICS” which is a new colloquialism used to designate the suffixes of various disciplines of biology such as genomic, transcriptomic, proteomic, and metabolic that comprise the analysis of complete genetic or molecular profiles of humans and other organisms.<sup>8</sup> The purpose is to get the collective quantification of pools of biological

molecules is to translate it into the structure, function, and dynamics of an organism or organisms.<sup>7</sup> The goals of precision medicine are to predict, prevent, and treat disease, to customize and provide “personalized treatments” for patients and bring the possibility of an earlier and accurate diagnosis.<sup>7</sup> AI in dentistry is building the path towards precision dental medicine that will customize the healthcare process.<sup>7</sup>

## **2. DESCRIBE THE MERITS AND LIMITATIONS OF VARIOUS TOOLS USED TO AID CLINICIANS DURING PERIODONTAL ASSESSMENTS**

In the current process of care with a patient, the clinician must perform a clinical periodontal assessment to determine a patient's periodontal status. A periodontal examination involves the evaluation of the oral tissues to assess for gingival inflammatory changes and measuring for attachment loss. Radiographs are also vital components of this assessment process and can be used to assess the presence of calculus, bone loss, and other local factors to establish a diagnosis and treatment plan. While the current process for periodontal assessment is considered the gold standard for determining a patient's periodontal status, AI is showing results to supplement this standard. The AI technology will not replace the manual methods of periodontal assessments due to the heavy reliance on the clinical assessment to distinguish some of the key factors for correct grading and staging. However, clinical assessments have their limitations that affect the outcomes and accuracy of the diagnosis. Limitations of these assessments include the positioning and adaptation of the periodontal probe, the diameter of the probe, the pressure applied when assessing the pockets, and the clinicians' judgment as to if they will round up or not when getting a reading that is in between numbers.<sup>9</sup>

Clinical assessments and manual assessments, are both reliant on the expertise of the individual examiner, and may be susceptible to contradictory measurements or conclusions drawn by different examiners at various stages of the diagnosis.<sup>10</sup> The time taken to effectively assess, identify and diagnose a patient's periodontal status correlates to the clinician's pace which will vary based on their experience and education.<sup>10</sup> Clinicians are also subjected to limited time

with each dental appointment, and the accuracy of a diagnosis is dependent on the amount of information each examiner has access to and the amount of time available to process it for their assessment.<sup>10</sup> Being that the periodontal assessment is based off of a mechanical stimulation and visual assessment, the comprehensive assessment of the bone and gingiva can be time consuming when completing a whole mouth examination, given that each tooth has between 4-6 surfaces to chart and examine.

The probe is essential in determining the periodontal status of a patient, but requires more time and is sensitive to the skill of the clinician. The conventional process of staging and grading a patient's periodontal health takes a generous amount of time, ultimately leaving the clinician feeling rushed during such a critical component of the assessment. However, AI has advantages in regards to periodontal assessment. Additionally, AI is a time saver in many aspects of healthcare and likely to be during the periodontal assessment.

In 2019, Krois J et al. compared the mean and standard deviation of six dentists versus CNN technology in identifying the radiographic bone loss (RBL) on radiographs.<sup>11</sup> According to the results, there was not a statistically significant difference in the means for identifying radiographic bone loss.<sup>11</sup> The means (SD) of six dentists for accuracy was 0.76 (0.06) and CNN was 0.81 (0.02) ( $p>0.067$ ).<sup>11</sup> This means that CNN was not statistically significant compared to the examiners and the use of CNN is just as accurate as a dentists findings. Although the results reflected that there is no significant difference in detecting RBL between the use of CNN versus dental clinicians, this is significant because CNN is only intended to help aid in clinical diagnosis. Furthermore, in 2018, Wiwiek Poedjiastoeti et al. demonstrated how CNN can be a significant time saver.<sup>12</sup> The results showed that the accuracy of detecting ameloblastoma between pathologists versus CNN was comparable at 83.2%.<sup>12</sup> However, the most significant

matter to note is the time it took for the pathologist to come to a diagnosis, which was 23.1 minutes versus with CNN which was approximately 38 seconds.<sup>12</sup> Considering the amount of time potentially saved in the periodontal assessment with the use of CNN, perhaps could give the clinician more time to focus on oral hygiene instruction with the patient and a more thorough debridement.

Technology has advanced our healthcare system with earlier diagnoses and better treatment options, but come at a cost. The approximate cost of implementing AI into an establishment is unclear. However, studies have suggested that the implementation of AI in healthcare will actually decrease the cost of healthcare in the U.S by 150 billion by the year 2026.<sup>2</sup> In addition, it shows that automated image diagnosis will have a value or savings of 3 billion dollars annually. This is because it is thought that AI demonstrates more of a proactive method in regards to preventing and diagnosing disease.<sup>2</sup>

However, few challenges arise when it comes to utilizing AI technology in healthcare. One main concern is protecting the patient's confidentiality as more advanced technology is further embedded into patient care.<sup>13</sup> CNN is primarily fed information, which is stored and converted to a numerical value.<sup>14</sup> However, the issue arises with sharing a patient's personal data with the machine and further sharing it with other establishments. This would require the use of cybersecurity to protect patient privacy. There also needs to be additional research on the ideal way to fully protect the personal information of a patient. Furthermore, another limitation foreseen in the use of AI is not only protecting the patient's confidentiality, but protecting the safety of the patient.<sup>13</sup> However, safety for patients is promising because there are already steps taken by the Food and Drug Administration (FDA) towards safety and the use of medical devices.<sup>13</sup> For example, FDA has already made a new category called Software as Medical

Device (SaMD) which demonstrates guidelines needed to be put in place for the safety of patients and the use of AI. Another common concern is liability.<sup>13</sup> If a patient were to experience an adverse reaction to AI, who would be responsible? Further research is needed to implement a protocol concerning liability, but currently multiple parties could be responsible.<sup>13</sup> A concern with the AI system is determining the accuracy of information put into the technology and the potential for bias it may hold.<sup>13</sup> To yield accurate results with AI, standardized formatting and labeling is critical.<sup>13</sup> For example, if you have periodontally involved radiographic images labeled inconsistently or in different formats, inaccurate results can be produced.<sup>13</sup> There are a number of merits and limitations in the conventional process and implementation of CNN in dentistry and specifically the periodontal assessment.



### **3. DISCUSS THE POTENTIAL INTEGRATION OF ARTIFICIAL INTELLIGENCE IN THE DENTAL HYGIENE PROCESS OF CARE.**

AI to assist the diagnoses of the periodontium can be done using 2D or 3D radiographs, tomography, or intraoral photos. In 2019, Joachim Krois et al compared the efficiency of CNN versus a clinician through analyzing 2D panoramic or periapical radiographs to classify teeth by being healthy or periodontally involved.<sup>11</sup> Before inputting the data into the CNN system, you must adjust the image by resizing, cropping, and changing it to grayscale. The more data input into the system, the more it learns. It will spot shapes, structures, etc to differentiate between periodontal compromised teeth or healthy.<sup>11</sup> A study using CNN to diagnose periodontally compromised teeth via 2D radiographs showed it to be as efficient as current diagnosis practices, but CNN was not statistically significant.<sup>11</sup> This technology introduced into private practice could assist the clinician by decreasing the time it takes for the clinician to look over the radiographs to diagnose periodontal compromised teeth, but the process of care still requires that the clinician use the other parts of assessment to make the final diagnoses. The implementation of AI into the analysis of radiographs wouldn't be a big transition since private practice offices take 2D radiographs already. It would require only that the CNN system be integrated and training completed by the clinician.

However, 2D images have several limitations, including image distortion, overlapping of anatomical structures, and the lack of ability to see three-dimensional features to assess relevant landmarks and pathological changes. Overall leading to a lower diagnostic accuracy of AI models trained using only 2D images.<sup>15</sup> In a periodontally involved case, a two dimensional (2D) image-based AI model built for the detection of periodontal bone defects might not be able to

detect three dimensional bony defects, loss of cortical bone plates, or bone defects around overlapping teeth.<sup>15</sup> Miki et al. developed a deep learning algorithm that was designed for automated filling of dental charts for forensic identification purposes.<sup>16</sup> However, it may also be valuable to incorporate it into the digital treatment planning system.<sup>15-16</sup> This type of algorithm in conjunction with the use of Cone- Beam computed tomography (CBCT) or 3D imaging could potentially aid the clinician in their periodontal assessments. The images being processed using the algorithm would help in updating patients' periodontal charts from year to year and give the clinician a better idea of where the more periodontally compromised areas in the mouth are, leading to a more efficient assessment. A CBCT image creates high-resolution three-dimensional (3D) images without distortion and overlapping of bone and dental structures as seen in many two-dimensional (2D) radiographs.<sup>15</sup> Being that periodontal assessments consist of evaluating hard and soft tissues, the CBCT or 3D imaging would help the clinician better assess due to clearer images and non-overlapping bone. Overlapping bone and unclear imaging as seen in 2D radiographs, could lead to a poorer outcome with this technology in the periodontal assessment.

In 2017, Balaei AT et al used intraoral photography with computer algorithms to identify healthy periodontium and periodontally involved periodontium.<sup>14</sup> The first computer algorithm identified the periodontium before scaling and root planning and the periodontium after periodontal treatment.<sup>14</sup> This showed a 66.7% sensitivity rate in identifying patients with periodontitis which means that CNN was correctly able to distinguish between health and periodontally involved.<sup>14</sup> The second computer algorithm used the difference in healthy and unhealthy teeth from the first algorithm to identify before and after photos of a periodontally treated patient.<sup>14</sup> This showed a 91.6% precision rate, recognizing how the disease was progressing.<sup>14</sup> There was a sample size of 88 intraoral images.<sup>14</sup> The researchers intended this

form of AI to assist patients that may not receive routine dental care, but do see a medical doctor.<sup>14</sup> This would allow for a medical doctor to use this form of AI to seek a diagnosis of periodontal health and be able to put in a referral. This would also allow medical doctors in all aspects of healthcare, that aren't familiar with dentistry, to monitor the progression of oral disease.<sup>14</sup> Intraoral photography images have also been used with CNN to detect plaque, which is an etiologic factor of periodontal disease. In 2020, You. W et al completed a study identifying plaque using CNN in comparison to the clinician.<sup>17</sup> Intraoral photos were taken of the primary dentition, then a disclosing solution was applied to the teeth to identify the plaque and photos were taken again.<sup>17</sup> 886 photos were used in this study.<sup>17</sup> As stated before, CNN detects spots, shapes, and structures. Putting these photos into the CNN system allowed for the technology to learn plaque patterns and differentiate between the normal tooth surface and a plaque accumulated tooth surface. The technology demonstrated to be statistically significant with a P value  $< 0.5$ .<sup>17</sup> The use of this technology in private practice can be used as an educational tool and gain patient acceptance by eliminating the use of disclosing solution which causes a temporary staining on the tooth surface.

## CONCLUSION

Artificial Intelligence using the technology of CNN, is a subdivision of computer science that is making a headway through the healthcare system to aid in healthcare and hopefully one day in dentistry to aid in periodontal assessments. Although further research needs to take place, implementing the use of AI during the periodontal assessment could benefit the patient and clinician by enhancing the efficiency in dental appointments and establishing more patient acceptance. The clinician is subjected to a limited amount of time to complete a comprehensive assessment of the entire mouth and cleaning as well, leading to an implication for the need of the use of AI in dentistry. Limitations in the gold standard mechanical periodontal charting further add to the need for a more efficient system to complete each dental appointment. With challenging the gold standard of periodontal assessment comes limitations; the main limitations with applying AI in healthcare in general involve handling ethical concerns like confidentiality, safety, liability, and consistent formatting. However, the use of the AI technique of CNN could offer quicker recall appointments, ultimately allowing the clinician to thoroughly clean and educate the patient. Currently, studies are being done using CNN to test out different forms of imaging to see which forms are most compatible in the field of dentistry, such as 3D imaging and ultrasound imaging. The research to date has shown no significant differences in the accuracy of CNN versus a clinician. In conclusion, more studies and research should be conducted to understand and fully develop the concept of using CNN in the dental hygiene process of care. There should also be more research conducted on the amount of time it takes a hygienist to adequately care for their patient, including assessment and treatment. While research has only scratched the surface of what AI could potentially do in the periodontal assessment of dentistry,

the implementation of AI in healthcare is endless. The future of dentistry and healthcare depends on the advancement of technology. While the use of AI and CNN technology may not be able to replace the gold standards of periodontal assessments, it is showing promising results in healthcare by growing and learning as a human does to help aid in these assessments. The more research that can be conducted in these specified areas, the more efficient and effective the dental clinician can become.

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