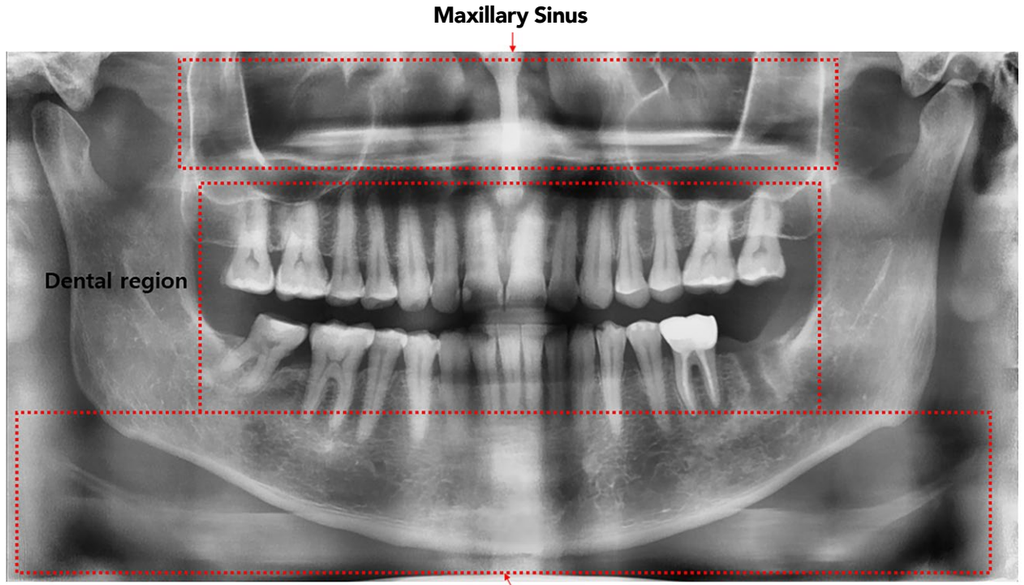
Detecting dental diseases with AI dental image analysis

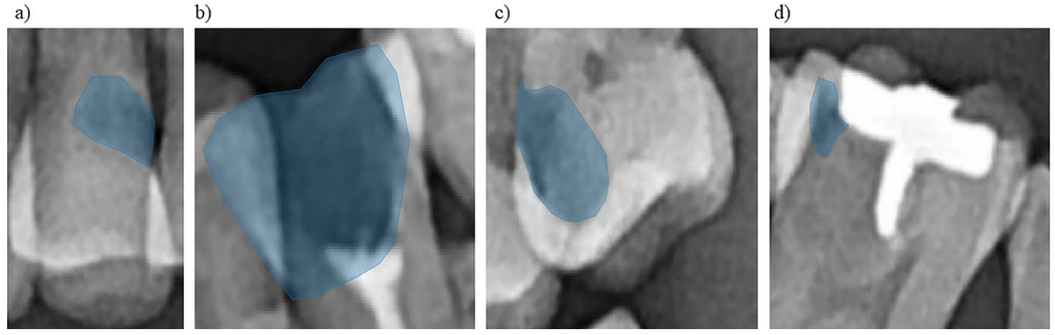
Dentists often use panoramic dental radiography, capturing the entire mouth in a single image, to diagnose dental diseases. The manual examination of these complex images is time consuming and laborious. Sangyeon Lee at the Korea Advanced Institute of Science and Technology (KAIST), together with Donghyun Kim, Dr Hogul Jeong, and Jaehyeong Park from InVisionLab, has developed a deep-learning model for AI dental-image analysis which enables the automatic detection of dental diseases from panoramic X-ray images. In addition to dental anomalies, radiographic findings from such images can be used in the diagnosis of systemic diseases.

Artificial Intelligence (AI) is employed extensively in dentistry to identify both normal and abnormal structures and diagnose diseases from the numerous medical images collected during a clinical routine. Panoramic dental radiography, which captures the entire mouth in a single image, is often used to diagnose dental diseases and plan subsequent treatment. These images are complex, and their manual examination is time consuming and laborious. In addition to dental anomalies, radiographic findings from such images can be used in the diagnosis of systemic diseases like hypo- and hyperparathyroidism (abnormally low or high levels of parathyroid hormone which affects calcium levels in the blood) and osteoporosis (porous bone). Due to time constraints, dental clinicians may concentrate only on teeth with symptoms, so the ability to filter out healthy images would aid diagnosis and save time.

Sangyeon Lee, a PhD candidate from the Department of Bio and Brain Engineering, Korea Advanced Institute of Science and Technology (KAIST), has collaborated with Donghyun Kim, Dr Hogul Jeong, and Jaehyeong Park from InVisionLab, to develop a deep-learning model for panoramic X-ray image analysis that enables the automatic detection of dental diseases.



Three major components of panoramic X-ray images.



Examples of labelled carious lesions: a) cervical caries or cervical abrasions, b) dental caries or coronal defects, c) proximal caries, and d) secondary caries.

AI DENTAL IMAGE ANALYSIS

The researchers explain how previous studies have employed AI in dentistry and been successful in the detection of targeted oral diseases. Still, they can only target a small number of abnormal signs or diseases. These models use convolutional neural networks to classify images and detect objects. They have not, however, exploited the key benefit of panoramic dental radiography in that it encapsulates the entire mouth in a single image. This includes the upper and lower jaws, individual teeth, and surrounding tissues and structures. Moreover, filtering out healthy images would reduce the number of images requiring manual examination and reduce the burden on dental clinicians.

Lee and his collaborators selected 17 fine-grained dental anomalies that can be detected from panoramic dental images. Using modern AI-based computer-vision techniques, they developed a model that can be applied in clinical practices to detect these anomalies. A huge number of high-quality data sets is essential for machine learning, so the research team collected 22,999 panoramic dental images from 30 local dental clinics over a year-long period from July 2020 to July 2021. Each image in the dataset was manually examined and labelled by a dental-radiography expert who noted any significant features or anomalies present in the image.

DENTAL ANOMALIES

The researchers describe how these major dental anomalies can affect both patients' dental health and their quality of life. If ignored, they can have severe consequences, particularly if they are connected to systemic diseases. Early detection can prevent serious outcomes and provide markers for other systemic diseases. The 17 anomalies were grouped into four categories based on their clinical features and locations: carious lesions, calcifications, anomalies in the dental regions, and anomalies in the surrounding regions.

These major dental anomalies can affect both patients' dental health and their quality of life.

Carious lesions, where there is a visible breakdown or a hole in the tooth surface, are the most common issue observed in dentistry. Their prevention and early diagnosis are crucial as they can cause more serious problems if ignored. The team divided carious lesions into four groups for fine-grained diagnoses to facilitate their early detection, preventing their progression and the deterioration of dental tissues.

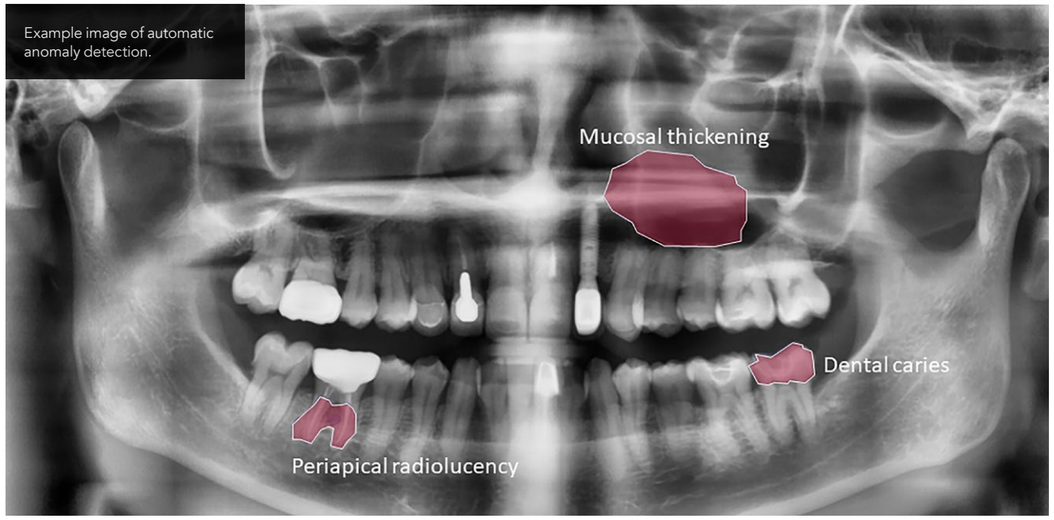
Calcification describe the build-up of calcium on the enamel and gums. Its presence on panoramic dental radiographs is rare, but detection is vital to prevent any further progression.

Anomalies in the dental area include dental disease features and abnormal forms of teeth that can cause symptoms, including bleeding, pain, and halitosis (chronic bad breath). The researchers chose to include six dental anomalies that are critical to dental health. These are external root absorption, impacted tooth, periapical radiolucency (radiographic changes that are often the result of inflammation), residual root, and supernumerary tooth. They can also be considered as diagnostic markers and anatomical factors to inform a patient's future dental work. For example, panoramic dental images can be used to evaluate the risk of nerve injury prior to an extraction.

Anomalies situated in surrounding regions outside the dental area are seldom connected with oral health. They indicate signs of inflammatory processes and can be markers for the diagnosis of other related diseases. For instance, the thickening of the mucous membrane in the maxillary sinus can be an indicator of conditions such as apical periodontitis (painful inflammation of the tissue surrounding teeth) and alveolar bone loss that occurs in the bones that support the teeth.

DETECTING ANOMALIES

The detection process is divided into four steps. The images collected from the dental clinics are in DICOM format. DICOM stands for Digital Imaging and Communications in Medicine and is an internationally accepted standard



Example image of automatic anomaly detection.

format for viewing, storing, retrieving, and sharing medical images. The first phase, the DICOM converter, involves converting these images into PNG format. Next is the disease detection stage; here, anomalies are identified using a trained Faster Regional Convolutional Neural Network (Faster R-CNN) model. This is an object detection model that detects boxed regions in the image where there are high possibilities of anomalies. The position verifier stage entails filtering out any boxes that are not located within a predetermined dental region. The final step is the polygon shaper stage, where a prebuilt library, Detectron2, is used to narrow down the region of abnormal signs from a box shape to a polygon. This enables dental clinicians to obtain high-resolution information regarding the location and anomaly types, as well as the precise regions that show the anomalies' features.

TRAINING, TESTING, AND EVALUATION

Lee and collaborators divided the 22,999 panoramic dental images into training, validation, and test datasets. The images from July 2020 to March 2021 were used for training this deep-learning model to recognise the 17 anomalies and validate the detection. The remaining datasets were used as a test set for evaluating the model.

The group used an intersection over union (IOU) value to evaluate their model's performance in correctly detecting lesions. IOU is an evaluation metric that measures the accuracy of an object detector. In this case, the area identified by the dental radiography expert is compared with the box identified by the model. The extent of overlap of two boxes is calculated by dividing the area of their overlap by the area of their union. If the two shapes overlap perfectly, the IOU score is 1. The researchers ascertained that an IOU value of 0.5 or more denotes a predicted box that has been correctly detected.

AI can be employed to alleviate the burden on dental clinicians, reducing the number of images that require manual examination.

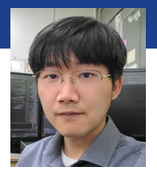
The class-wise performance of the detection model was compared with the labels provided by the dental radiography expert and measured in terms of precision, sensitivity, and specificity. The precision and sensitivity scores vary according to the anomaly types, with scores that exceed or match those from previous studies. The model demonstrated very high specificity, more than 95% in most classes, showing that it can successfully detect abnormalities and filter out normal healthy images. This high specificity indicates that this artificial intelligence model can reduce the burden of examination for dentists as it successfully filters out the healthy images and allows clinicians to focus on those images with potential anomalies.

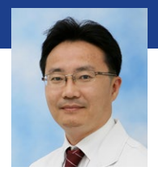
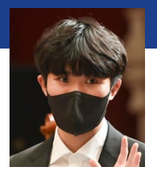
TRAINING A DEEP-LEARNING MODEL

The researchers discuss how the quantity and quality of the data are key when using AI techniques. Training their deep-learning model to detect 17 types of anomalies involved accruing datasets with sufficient examples of each class of object to be detected. They created a system that collects panoramic dental images direct from the dental clinics for a year, and a dental radiography expert labelled them manually. This high-quality dataset is still accumulating and can be used for future research.

The high-performing tool successfully detects anomalies and filters out healthy images. Its high sensitivity (approximately 0.99) validates its suitability for use in real clinical practices and demonstrates how AI can be employed to alleviate the burden on dental clinicians, reducing the number of images that require manual examination. This deep-learning model encompasses a large area of panoramic radiography and will help dentists improve patients' quality of life through early diagnosis and prevention of diseases.

Behind the Research



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Research Objectives

Mr Lee and his collaborators have developed a deep-learning model that can detect dental diseases from radiography images.

Detail

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Bio

Sangyeon Lee is a PhD candidate in the Department of Bio and Brain Engineering at Korea Advanced Institute of Science and Technology (KAIST). Main research fields are bioinformatics and data science.

Donghyun Kim, CEO of InVisionLab: Major in electrical and electronic engineering at Korea Advanced Institute of Science and Technology (KAIST). He worked for ten years at medical service companies and became interested in the convergence of the medical industry. As a doctoral student at Yonsei University School of Dentistry, he studies the convergence of technology and dental medical service.

Hogul Jeong, Head of research institute at InVisionLab: PhD in dentistry from Yonsei University College of Dentistry. With more than 20 years of experience in the dental imaging and diagnosis field, he is researching dental image diagnosis and artificial intelligence.

Jaehyeong Park, Programmer at InVisionLab: Majoring in computer science and engineering at Seoul National University, he works at InVisionLab as a programmer, developing front-end services and other applications. He is also a cellist at the Seoul National University Amateur Orchestra.

Funding
InVisionLab is a company developing automatic analysis and diagnosis of clinical dental images like panoramic X-ray, CBCT image diagnosis, and cephalometric images.

References

Lee, S, Kim, D, Jeong, HG, (2022) Detecting 17 fine-grained dental anomalies from panoramic dental radiography using artificial intelligence. *Scientific Reports*, 12, 5172. doi.org/10.1038/s41598-022-09083-2


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Personal Response

What motivated you to develop this deep-learning model?

"Many diseases can be detected in the early stages from the panoramic X-ray image, and these early detections can increase patients' quality of life. However, it takes too much time for dental clinicians to examine all newly taken images every day. We therefore decided to help both dental clinicians and patients using AI. By suggesting the possible regions of dental anomalies and normal images which don't need further examination, the AI system can reduce the burden for clinicians so they can focus on their patients and treatments."