APPLICATION OF ARTIFICIAL INTELLIGENCE IN DENTISTRY

1.General Dentistry:

The beauty of AI lies in the fact that machines can be taught to analyze extensive data sets and learn from them to provide optimal diagnoses. Virtual dental assistants powered by artificial intelligence can perform various tasks in routine dental practice with less human resources, fewer mistakes, and greater accuracy than humans. They aid in scheduling appointments, managing insurance and paperwork, as well as assisting in clinical diagnosis and treatment planning. Additionally, they help alert dental practitioners about patient's medical histories and habits such as smoking and alcohol consumption. In dental emergencies when the practitioner is unavailable, patients have the option of emergency teleassistance, which can be highly beneficial.

AI has now become an integral part of our daily lives, with the emergence of Siri and Alexa allowing us to use voice commands. The dental practice has also been updated, moving from touch-sensitive dental chairs to voice-controlled ones that require no manual input from clinicians. The chair positions, water dispensing, and light control can be efficiently managed based on voice commands. Furthermore, a relatively sterile form of clinical examination can be carried out with a reduced risk of cross-contamination during treatments. Thus, a detailed virtual database of the patient can be created, which will greatly aid in providing the best possible treatment for the patient[3]

2.Diagnosis, Treatment plan and Data management

The diagnosis of dental conditions involves the interpretation of patient data obtained through observation and examination, the formulation of a diagnosis, and the development of a treatment plan. To achieve this, an intelligent system is required to analyze the input data and generate a personalized output. Artificial intelligence (AI) enables a more systematic and organized collection of patient data, reduces routine tasks, promotes research and development, and offers a promising alternative to a more participatory healthcare system. AI focuses on building a robust system for each process by extracting relevant data from a large repository of medical records to assist dental professionals in making informed decisions and aid patients in understanding their condition and prognosis.

Clinical Decision Support Systems (CDSS) were designed to manage the increasing volume of patient data over time and analyze it using a built-in clinical database, thereby assisting dental professionals in making decisions regarding diagnosis, prevention, treatment, and prognosis of the condition. The CDSS operates by classifying a patient with a toothache based on their caries risk assessment, using a short questionnaire that includes their last visit to the dentist, past restoration history, sugar exposure history, and fluoride exposure history. An automated treatment plan is then generated, providing valuable information to the dentist and patient, while also saving time and improving efficiency[8]

3. Implementation of artificial intelligence (AI) techniques in the field of orthodontics and dentofacial orthopedics.

The future of orthodontics is no longer reliant on appliances, but rather on AI. Recently, AI has been used to analyze radiographs and photographs to aid in orthodontic diagnosis, treatment planning, and monitoring treatment progression. In addition, intraoral scanners and cameras are replacing dental impressions with digital impressions, which are fed into algorithms and AI software to predict tooth movements and treatment outcomes. By combining the latest technologies with customized aligner-based orthodontics, case acceptance can be improved[4]

To achieve successful orthodontic treatment, accurate diagnosis, treatment planning, and prognosis prediction are crucial. AI technology has been utilized to determine the necessity of extractions prior to orthodontic treatment. A study by

A researcher used an artificial neural network (ANN) model to analyze lateral cephalometric radiographs and accurately predict the need for extractions. In a study it was showed 92% accuracy in using an AI expert system to decide on permanent tooth extraction. These results suggest that AI models canbe effective and accurate in predicting the need for extraction and can be used as a tool in clinical practice. A researcher demonstrated high accuracy in an AI model based on Bayesian network (BN) for assessing the need for orthodontic treatment.

AI can also be used for treatment need assessment and outcome scoring in pediatric orthodontics. Bayesian network and support vector machines (SVM) have been used to diagnose orthodontic treatment needs and assess fixation time of lay persons viewing patients, respectively. Convolutional neural networks (CNNs) have been utilized to characterize specific facial traits for attractiveness scoring and apparent age estimation. The introduction of AI in pediatric orthodontics can provide an objective and reproducible interpretation of facial appearance[5]

Pediatric orthodontic treatment heavily relies on diagnosis, which involves the analysis of radiographs and photographs. With the emergence of intraoral scanners and cameras, digital impressions have replaced traditional dental impressions. AI algorithms and software utilize these inputs to predict tooth movements, treatment outcomes, and determine the need for tooth extraction, anchorage patterns, and other factors that influence decision-making in orthodontic treatment. Customized aligner-based orthodontic treatment, combined with the latest technologies, can significantly improve case acceptance. A new system has been developed that generates dental arch forms and can bend orthodontic wires. Virtual articulators can simulate occlusal changes in the digital world, which may be further enhanced by AI in the future to simulate dental material use and treatment outcomes of implant placement or maxilla-facial surgeries

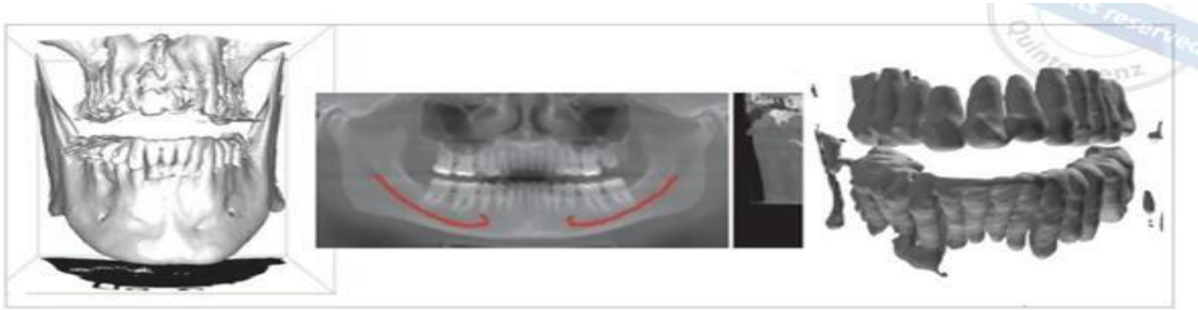

Fig: Automatic structure segmentation, annotation and data conversation

Figure: Automatic customized tracing and cephalometric analysis with AI technology.

Utilizing CBCT scanning, artificial intelligence can accurately identify landmarks necessary for cephalometric analysis. Researchers have developed an Expert System (ES) in the field of orthodontic research. The ES is primarily involved in processing knowledge and information, aiding dentists in decision-making processes to solve problems[6]

Diagnostic imaging such as computed tomography scans, magnetic resonance imaging scans, and periapical radiographs can provide valuable input for augmented reality (AR) information. This allows dentists to obtain critical information about root canal anatomy while keeping their focus on the operating field, unlike conventional systems. The real-time presentation of three-dimensional information on the patient's body is more efficient and less confusing than presenting it on a separate screen. Success has been reported in orthognathic surgery and implant placement using Head Mounted Display (HMD). Guided bracket placement in pediatric orthodontics and orifice detection in endodontics were achieved using k-nearest algorithms and Euclidean distance-based segmentation. Robotic assistance significantly increased the success rate of endodontic procedures from averages of 60-70% for general dentists and 80-90% for endodontic specialists. This also improves time efficiency and avoids injuries resulting from consistent unergonomic postures. Orthodontic movements such as rotation, translation, or a combination of both can be carried out within minutes to a few hours[12]

4.Endodontics

Dental professionals who have been working for extended periods may experience fatigue and exhaustion, leading to possible oversight of dental caries during examinations. The integration of AI software can provide significant benefits in assisting dentists to identify caries lesions on radiographs. According to researchers, bitewing intraoral radiographs are effective in detecting dental caries in its early stages, increasing awareness of oral health conditions and allowing for preventative treatments.

AI technology can accurately locate tooth areas susceptible to caries and complex peri-apical pathoses, define lesion boundaries with precision, and differentiate between different pathologies. Logicon Caries Detector can detect and characterize proximal caries, analyze the lifespan of restorative materials, and locate minor apical foramen (AF) for more accurate working length determination[1]

Endodontic procedures require high precision, and dentists specializing in endodontics often work with magnification to ensure proper root canal treatment. A proposed robotic system called the "vending machine" can provide necessary instruments during treatment to reduce the dentist's deflection from the operating site[2]

In-vitro testing has been conducted on micro-robots with catalytic abilities for the destruction of biofilms in root canals, which may have potential applications in preventing tooth decay and peri-implant infection.

Convolutional neural networks (CNN) with deep learning (DL) have become increasingly prevalent in cariology and endodontic diagnostics. DL can automatically segment lesions in radiographs or images, making analysis more convenient. Using an encoder-decoder architecture (U-Net), DL segmented CBCT voxels into various categories, including "lesion," "tooth structure," "bone," "restorative materials," and "background," achieving results comparable to those of clinicians in diagnosing periapical lesions. DL can also identify proximal carious lesions from near-infrared transillumination images with an area under the receiver operating characteristic curve of 0.856.

Volumetric measurement in CBCT, following DL-based segmentation, was reported to be comparable to the results obtained from manual segmentation of periapical lesions .However, this research did not report outcomes such as the volume deviation of lesions and the Intersection over Union metric. This oversight challenges the reliability of the results. Several studies have explored automated detection of periapical radiolucency using either OPGs or CBCTs. Computer vision and neural networks facilitate interpretation of CBCTs at a level uninterpretable to human vision[10]

Early detection of periapical lesions may prevent complications and improve patient outcomes. In one study, the CNN trained and validated on 2902 OPGs outperformed 14 of 24 oral maxillofacial surgeons who had varying degrees of professional experience. In another study based on 85 OPGs, the ML model achieved sensitivity of 0.65 and specificity of 0.87. A neural network for image segmentation trained and validated on 20 CBCTs achieved a sensitivity of 0.93 and specificity of 0.88. A neural network was designed to detect vertical root fractures (VRF) in endodontically and non-endodontically treated single-rooted premolar teeth using periapical radiographs and CBCTs. Detecting VRF on CBCTs significantly outperformed periapical sowing due to difficulties in ensuring the beam is perpendicular to the fracture in periapical achieving sensitivity and specificity of 93.3% and 100%, respectively[15]

Generation	Specification
First-Generation	Kedo-S rotary file is a single NiTi rotary file system consisting of D1, E1, and U1 files, wherein U1 files are for upper and lower anterior primary teeth, D1 for mesiobuccal and mesiolingual canals, and E1 for distal and palatal canals of the primary molar teeth. They have a working length of 12 mm with a total length of 16 mm. The uniqueness of these files is the presence of variable taper (4%–8%) with varying tip diameter
Second Generation	Kedo-SG rotary files are heat-treated NiTi rotary files utilizing the M-Wire technology. These files result in better obturation quality due to its efficient preparation of primary root canals
Third Generation	The next generation is the Kedo-SG Blue consisting of three files D1, E1, and U1, which have greater cyclic fatigue resistance with its titanium oxide coating. These files are super flexible and have 75% of greater resistance to cyclic fatigue than its earlier generation
Fourth Generation	The newer generation Kedo-S Square consists of P1 file for molars and A1 file for anteriors. They also have variably variable cross section; that is, the apical 5 mm has triangular cross section with three-point contact to root canal, whereas the coronal 7 mm has teardrop cross section with two-point contact. This enables reduced apical dentin removal and less aggressive preparation

(i)Endo Micro Robot

The success of endodontic treatment relies heavily on the clinician's knowledge, expertise, tactile sense, and judgment. Unfortunately, endodontic mishaps such as canal ledging, perforation, stripping, apical foramen transportation, and excessive instrumentation beyond the apex may occur during the root canal preparation process. To enhance the quality of endodontic treatment and reduce the potential for human error, advanced endodontic technology innovation is necessary. This can be achieved by integrating advanced engineering and computer-aided technology[13]

The Advanced Endodontic Technology Development project encompasses four sub-projects:

1. Development of a technique to evaluate the tooth's condition comprehensively using 2D x-ray images and creating a computer 3D tooth model that displays state-of-the-art computer graphics.

2. Development of an automated prescription system from the 3D root canal model using computer-aided treatment procedure planning.

3. Designing and constructing a smart multi-purpose precision micro-machine that can perform automated root canal treatment.

4. Developing a new ultrasonic cleaning tool with pressure-assisted jetting/vacuum waste removal.

This computer-controlled machine will be mounted on several teeth in the patient's mouth. The micro-machine or robot will perform the automated drilling, cleaning, and filling of the root canal with online monitoring and intelligent control. All other sub-project results will be incorporated into this robotic operation. The micro-robot design aims to:

1. Reduce the dentist's reliance on skills.

2. Minimize human error.

3. Provide a precise diagnosis and treatment method.

Features of Micro Endo Robot

- A micro-position and orientation adjustment to ensure that the tools start at a precise point;
- An automatic feed rate and travel distance control to ensure that the tools can reach the required canal depth and stop at a designated point;
- Built-in micro sensors to monitor the probing and drilling/reaming process;
- Apex sensing and control to prevent root perforations or the potential to over shoot (exceeding the apex of the canal);
- Flexible drills or files to allow for cleaning and shaping curved canals.
- Vacuum attachments capable of sucking the debris or loose tissue from the root canal and/or pressurized solution jets to flush the chips away.
- A preliminary quantitative study established the design requirements.

In order to provide accurate positioning of the tool, with correct angular orientation, an ideal basic machine must have five degrees of freedom to control the following axes:

- X-axis, along the teeth row, with travel range of 5 mm;
- Y-axis, across the teeth row, with travel range of 4 mm;
- Z-axis, the tool advancement direction, perpendicular to the tooth occlusal surface, with a travel range of 15 mm minimum. When using a longer tool, the endodontic tool should be able to reach 28 mm from the tooth crown, covering the required range of treatment;
- The angular adjustment of the tool entrance angle of ± 12° in the X-Z plane;
- The angular adjustment of the tool entrance angle of ± 12º in the Y-Z plane. The size of the machine must be compact enough to fit into the patient's mouth and sit on the teeth between his/her two jaws. The dimension should be within 20mm x 20 mm x 28 mm;

- The spindle must have the rotational power to drive the tool at speeds and torque used in endodontic treatment tools;The machine should be able to provide a thrust force not less than 500gm for tool penetration into the crown and dentin

The base of the machine is shaped like a saddle and will rest on a pair of reference clips and the teeth. Before taking X-rays and attaching the machine, the clips, which come in different sizes to fit the patient's teeth, need to be securely fastened to the tooth that requires treatment. Adjacent teeth can serve as support. The pair of clips serve as three radiopaque reference points to register the machine, thereby establishing a coordinate system. Once the machine is placed on the reference clips, the base will remain stationary in relation to the patient's teeth, irrespective of any movements made by the patient's head or jaw. The machine has a compact and sturdy design, allowing the patient to bite onto it without the need to keep their mouth wide open or their head perfectly still. This machine can be used for multiple purposes and can accommodate various endodontic tools and accessories. A quick tool change mechanism, using a cartridge design, enables different tools to be pre-mounted on a small modular unit that can be inserted into a sliding adaptor on the Z-axis of the machine.

(ii) Micro Sensors, Actuators, and Control Systems

This apparatus's blueprint also encompasses detectors for intelligent supervision of the treatment procedure. As a result of the sensors small size, they can be manufactured using a surface micro-engineering technique to produce silicon-on-insulator (SOI) wafers, which will be integrated into the micro-robot. The tool's five axes (five degrees of freedom) and the on/off spindle are controlled by six micro-actuators. Each actuator is autonomously controlled by a digital NC controller. The controller must respond to the sensor signal swiftly, normally within a few milliseconds. Additional functions provided include an irrigation nozzle for cleaning, a vacuum suction cup for chip and waste fluid removal, and/or optical fibres for illumination, imaging, and observation. A clinician's manual remote control will be provided, but a fully automatic operation aided by a computerized treatment procedure planning and control system is the ultimate goal for a zero-defect operation. An interface system will be provided for the clinician to interact with the machine control. The computer-aided treatment process planning system, which has functions similar to CAD/CAM programs in the machinery industry, will generate standard NC codes (G codes and M codes) as output from a computer-aided design file. These codes will control the movements of the robot through an NC digital controller.

This computer prescription program is being developed to automatically select the appropriate tool and to determine:

(1) The tool’s starting point, position, and direction,

(2) The tool’s path;

(3) The tool’s stopping point,

(4) The cutting parameters, such as speed and feed, and

(5) The geometry of the 3-D tooth model aftertreatment.

The computer software will strategize the sequence of actions utilizing various tools and motion control parameters to accomplish the preparation of the root canal. An optimization algorithm will be incorporated into this automated prescription software to minimize tooth structure removal and avoid unnecessary tool switching[11]

Advanced Endodontic Technology Development is focused on creating an endodontic micro robot that offers a less invasive approach to root canal therapy than traditional access methods. This method employs automated access and canal preparation during endodontic treatment, reducing the risk of human error.

In Cariology and Endodontics, machine learning algorithms such as SVM, RF, and k-nearest neighbors were utilized to create predictive models that identify individuals at risk of tooth surface loss and root caries. SVM demonstrated the highest accuracy of 97% and sensitivity of 99.6% by analyzing patient data such as demographics, nutrition, lifestyle, and clinical information. Additionally, by using 83 features from the American Association of Endodontists' "Endodontic Case Difficulty Assessment Form," SVM and ANN achieved over 90% accuracy in predicting the level of difficulty of cases requiring root canal treatment. This showcases the potential of machine learning to improve the decision-making capabilities of general dental practitioners when referring patients to endodontists[16]

Presently, the main focus of machine learning research is to identify primary carious lesions in dental images. One ML algorithm scrutinized 3686 bitewing radiographs and conducted semantic segmentation to classify caries pixel by pixel. In the detection of initial lesions, the CNN model surpassed seven dentists with clinical experience ranging from 3 to 14 years and was more effective than the majority of experienced dentists. Another CNN model was trained and tested on 3000 cropped periapical images to classify caries. This model exhibited superior performance in detecting caries in premolars (AUC = 0.917) compared to molars (AUC = 0.890) due to the greater complexity of the morphological structure of molar teeth. A customized neural network was employed for semantic segmentation to detect occlusal and proximal carious lesions in 185 DIAGNO CAM near-infrared transillumination images. The dental experts and the ML model only had a 49% agreement in the areas marked as caries. However, DIAGNO CAM is not widely available in dental practices, and BW radiographs have been demonstrated to have the highest sensitivity and specificity for the detection of occlusal and proximal caries. Dentists do not solely rely on dental images to diagnose and manage dental caries. A common limitation in the current research on automated caries detection is the exclusion of patient history and clinical examination findings. Moreover, the question remains unanswered whether an ML model that outperforms dentists in detecting caries in radiographs ultimately leads to better clinical outcomes for the patient. The contemporary shift in caries management is towards minimum intervention dentistry; therefore, identifying and eliminating risk factors that contribute to disease progression is crucial in achieving stability before any treatment. Several ML models were developed to predict the risk of root caries by considering demographic and lifestyle variables using 5135 combined interviews and clinical examinations.

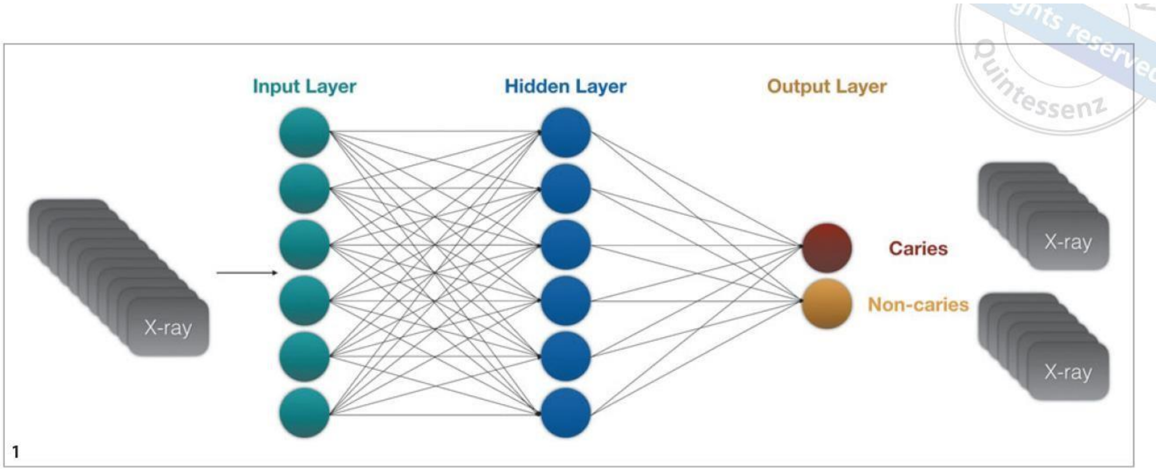

Fig 1 The example of deep learning with the application of detecting caries using radiographs. The radiographs will be imported to the software as the input layer. Through multiple "hidden layers," the algorithms will classify imported radiographs as "caries" or "non-caries" based on the AI training.

Identifying individuals at high risk of disease progression at an early stage can help prevent or intervene in the disease process. The SVM model demonstrated excellent performance with an AUC of 0.997, 99.6% sensitivity, and 94.3% specificity.

Additionally, while age was predictably the most significant predictor of root caries risk, the ML model identified unexpected factors such as computer usage, television viewing hours, and sunscreen use. Although ML uncovers unexpected relationships, these variables are not the root causes of root caries. They do, however, offer insight into individual lifestyle factors that can be integrated into a patient-centered care approach for the diagnosis and treatment planning of root caries. By processing vast datasets that might not otherwise be considered, ML models may serve as a supplementary tool to the clinician's intuition in predicting future caries risk[14]

5. Preventive Dentistry

In addition to its usage in dental diagnosis, therapy, and management, artificial intelligence has displayed enormous promise in preventing and monitoring infections.

The monitoring of healthcare-related infections (HAIs) can greatly enhance early detection of certain illnesses, trace the spread of diseases, and generally aid in the monitoring and control of infections. This can help identify "weak spots" so that practitioners can apply appropriate preventive measures and take action accordingly. An HAI surveillance program utilizes databases from various sources to evaluate emerging disease outbreaks and analyze patterns and indicators in detail. In other words, an HAI program measures the incidence of HAIs and evaluates the severity of diseases. In certain cases, it can assist in determining patient outcomes or evaluating the quality of care. Recent studies indicate that social networks of patients and caregivers with HAIs and data obtained from electronic health records (EHRs) that are otherwise collected for other purposes can successfully generate probabilistic simulations of nosocomial outbreaks of methicillin-resistant Staphylococcus aureus and influenza. Similarly, EHRs that use machine learning applications have proven to be invaluable in predicting the risks of nosocomial Clostridioides difficile infection (CDI) , thus avoiding or mitigating severe complications. The advantage of the machine learning method over traditional CDI risk grouping is that the AI program refers to processing existing risk factors and employs a wide range of variables within the EHR. Therefore, this technology can create various models to cater to the specific needs/activities of either patient or caregiver populations. As a patient's CDI risk is likely to change during their inpatient stay, the machine learning application used for surveillance purposes is reported to function flawlessly and alert caregivers to any unexpected changes accordingly. Such a personalized approach to patients at high risk of developing CDI needs to be further supported by practical evidence in clinical trials and other relevant research studies focused on HAI. However, it is evident that it has strong potential for upgrading HAI surveillance and IPC (infection prevention and control), and that similar or more advanced AI solutions would be considered invaluable.

It can lead to inaccurate predictions and hinder the generalization of AI models to other healthcare settings. Therefore, it is crucial to ensure that the data collected is diverse and representative of different populations and healthcare systems. Additionally, the implementation of AI in clinical practice requires a significant investment of time and resources to ensure that it is properly integrated into existing workflows and that healthcare professionals are appropriately trained to use it. Nevertheless, overcoming these challenges will enable us to leverage the potential of AI to improve HAI surveillance and control, ultimately leading to better patient outcomes and reduced healthcare costs which might affect the treatment once they become an integrative part of a machine learning model . Another downside of AI in HAI might be the potential generalization of machine learning models for HAI surveillance which could not be applicable in every health-care setting. For instance, one CDI model can feature risk factors for CDI in one context, but they might not work in the same way for other settings[17]

6.Artificial Intelligence Algorithms and Nutrition in Preventive Dentistry

Observing the dietary habits of patients is a crucial aspect of preventive dentistry. The type of food we consume and how often we eat it are directly linked to oral diseases, especially cavities. Advanced AI algorithms are progressively being utilized in clinical nutrients research, which is applied in supporting dietary activities, assessing risks related to food-related dental diseases, and monitoring general nutrient habits.

AI has become significant in prophylaxis through dietary assessment mobile applications. Researchers reported a successful design of an electronic photographic method and image processing algorithms that estimate food intake. Researchers developed go FOODTM, an artificial dietary evaluation system based on AI that requires input information through sample photographs taken by a smartphone. This system calculates the calorie and macronutrient content of a meal, providing a reliable dietary assessment. Similarly, Researchers introduced Ontology for Nutritional Epidemiology (ONE) as an authentic tool for easier integration, visibility, and connectedness of research findings in nutritional epidemiology. This research offers a more objective dietary assessment.

Researchers designed a dietary evaluation system based on a specific neural network that calculates food volume. They utilized a set of visual data to develop a neural network using the deep learning approach. Another group of researchers approximated food energy based on images and the generative adversarial network (GAN) architecture from mobile phone images of food portions over a week with a sample of 45 respondents[17]

Another image-based research study appraised the respective rationality of an image-based dietary evaluation app entitled Keenoa, designed through the food diary notes of a group of a hundred adults during a 3-day period . The research showcased that the Keenoa app has demonstrated significant advantages if utilized for dietary assessment of the general population, whereas its use for personal assessment remains prone to errors. One similar research project centred around the application of AI in nutrition deployed the fuzzy decision model for designing an online support system aiming to browse the available food constitution databases as a basis for calculating dietary intake. The rationale behind this research project was the necessity of designing guidelines for Taiwanese dietary practitioners who are reported to have poor databases of Chinese menus and need a reliable decision-making tool

As AI technology continues to advance, it is increasingly being utilized to assess the quality and quantity of nutrition. However, despite numerous studies confirming the potential of AI apps and tools in this field, there is still room for more complex algorithms to be developed. Such developments could be particularly significant in addressing the global obesity epidemic. For example, researchers have already used the Internet of Things (IoT) approach to create a monitoring system that tracks personal activities through sensors on a smart-log patch. By processing this data through a Bayesian deep learning network (EC-BDLN), they were able to gain valuable insights into cardio-metabolic caries risk factors in the general population. Similarly Researchers have investigated the use of machine learning algorithms such as support vector machine (SVM), neural network, and k-nearest neighbour (kNN) calculations to determine observable traits in female built.

Despite these promising developments, there is still a considerable lack of more complex AI algorithms that could be utilized for similar purposes. One possible solution to this issue may be to incorporate research on the use of medical robotics into the development of AI tools for nutrition assessment. However, this will require a shift in mindset and skills among practitioners in both the medical and food industries. Only by embracing the demands of future research can we fully realize the potential of AI technology in the field of nutrition[21]

7. Caries Prevention

Recent studies have suggested that genetic factors play a significant role in the development of dental caries. Therefore, there is a need to develop new Caries risk predicting models (CRPMs) that take into account both environmental and genetic factors to accurately predict caries risks. According to recent research, dental caries is the most prevalent chronic disease worldwide in 2016. The treatment of caries has also become a significant financial burden, reaching 540 billion dollars globally in 2015.

As such, it is imperative to take immediate action to prevent caries risks. Studies have shown that there has been a shift in the distribution of caries, with adolescents now being the most affected group. Scholars have recommended that more attention should be paid to individuals who are at risk of developing dental caries to prevent and control the disease. AI-based tools and applications can be used to implement risk prediction models for early diagnosis and precise examinations in adolescents at risk of developing caries[18]

CRPMs are non-invasive treatment approaches that have significantly improved patient care. There are currently four standardized

CRPMs in use: ADA, CAT, CAMBRA, and Cariogram. However, these models only consider environmental indicators and do not take genetic factors into account.

New CRPMs that consider both environmental and genetic factors are needed for accurate caries risk prediction. and behavioral factors, including plaque index, the number of *Streptococcus mutans* and *Lactobacillus*, saliva flow, and salivary buffer capacity. There is a consensus that the Cariogram seems to be the one more advance and accurate of all the mentioned CRPMs for certain tests. However, it fails to prove its efficiency in caries prediction. As evidenced Researchers, Cariogram demonstrates different sensitivity scopes, ranging from 41.0 to 75.0%, whereas the specificity ranged from 65.8 to 88.0%

The development of dental caries is a result of a complex interplay between genetic and environmental risk factors. Environmental factors such as poor dental hygiene, excessive sugar consumption, dental plaque, and saliva quality are commonly reported as determinants of caries risk. However, genetic factors also play a significant role, with genetic risk scores accounting for approximately 49.1% to 62.7% of the variation. Caries risk is a unique genetic phenotype that can be influenced by various other factors, including food habits, immune system functioning, saliva composition, taste perception, and enamel formation. For instance, scholars have found a correlation between high-risk caries and a variation in enamelin (ENAM). Additionally, research suggests that the relationship between genetic variation in tuftelin (TUFT1) and caries is only apparent when Streptococcus mutans levels are high. Therefore, relying solely on environmental factors to assess caries risk may overlook crucial genetic information. Combining genetic and environmental factors in a risk prediction model provides a more accurate prediction of caries risk. Such models have been shown to be more effective than using environmental factors alone

This indicates that it is important to investigate and study CRPMs with practical applications related to both factors so that the prediction of caries risk can be carried out with greater accuracy .Researchers presented an innovative caries risk prediction model, which was the first to be developed with both of these predictors. This model incorporates ML algorithms and includes factors such as "plaque index," "cariostatic score," and "past caries experience," with the latter being one of the most significant predictors of individual risk. Interestingly, this CRPM model includes a factor that confirms whether the patients "were only teenagers in the family.

In a comparable Cariogram model developed by researchers named as"cariostatic score" was used instead of "bacterial counts" to assess the cariogenic ability of dental plaque. Cariostat employs "a colorimetric test to assess the acid produced by bacteria in the plaque." .A research study shows, the development of carious lesions occurs when bacterial acids affect dental tissues, causing demineralization. The demineralization process is triggered when the pH level on teeth surfaces drops below 5.5. In this sense, Cariostat, as a model, can effectively assess the microbiological quality of caries and, in contrast to other cariogenic tests such as Dentocult SM, focuses on bacteria assessment rather than saliva in plaque. This model promises to provide greater accuracy in evaluation as cariogenic bacteria develop in plaque form. Overall, as these studies indicate that CRPM models provide significant informational support, policymakers can make more informed decisions on prevention policies for high-risk groups in the general population[22]

With approximately 1.8 billion new instances occurring annually worldwide, early childhood caries (ECC) is a persistent childhood ailment. AI can provide innovative and dependable solutions to enhance ECC detection and implement new treatment methods, particularly when paired with interactive oral health education provided through mobile applications. The current biomedical techniques used in ECC control yield poor outcomes due to their focus on individual treatment procedures rather than preventative measures for the general population. In order to prevent further tooth decay and its effects on dental hard tissue, dental caries must be identified in the early stages of development when white lesions appear on the enamel surfaces[19]

8.Oral Hygiene

The objective of maintaining good oral health is to regularly remove plaque that accumulates around the gum line and between teeth, in order to prevent bacterial colonization which is a crucial factor in causing tooth decay. To achieve this, individuals should use a mouthwash, toothbrush, or a combination of both, and also remove secretions from the mouth. As newer electric toothbrushes are introduced to the market, people's brushing techniques are constantly improving. Smart toothbrushes are equipped with 3D sensors that can detect position and orientation in various brushing areas in real-time, and analyze parameters such as accuracy, duration, and frequency.

Typically, oral hygiene behavior is assessed through standard indicators such as dental plaque, periodontal inflammation, and tooth decay, and through patients reporting their oral hygiene practices during clinic visits. However, when dealing with large groups of people, these methods can become cumbersome, especially if individuals do not have regular access to dental services. To better understand the relationship between oral hygiene behavior and outcomes such as plaque and dental disease, new systems that can provide real-time monitoring and feedback should be implemented. Dental professionals should emphasize the importance of good oral hygiene and incorporate feedback mechanisms to encourage patients to adhere to recommended practices. Additionally, the use of smart systems combined with oral hygiene practice measurement and feedback devices, supported by risk prediction and customized prevention algorithms, can provide high-quality, patient-cantered care. This would give a digitally involved patient more control over their oral health and subsequently make them more involved.

The device can track skipped places and offer custom suggestions in regard to oral care, thanks to artificial intelligence (AI) and machine learning algorithms. User application of too much pressure and teeth that require more attention and percentage of brushed surface are all shown on a tooth map. Suppose the person applies too many pressure tests possible to cause gingival damage; therefore, it’s important to prevent that. Thanks to AI-powered examinations, patients have no trouble getting a total and accurate mouth cleaning. This includes enhancing their technique, completion of brushing on missed surfaces, and maintaining not too harsh of a pressure. In no time, they will have a perfect oral hygiene routine without missing a tooth. Serious caries complications can be prevented by involving smart toothbrushes in a hygiene program. One issue that needs to be approached directly and further investigated for the implementation of these devices is their marginal markup in price in comparison to standard toothbrushes. They usually have a replaceable brush head

9.Oral and maxillofacial surgery

According to the World Health Organization, there are approximately 657,000 new cases of oral and pharyngeal cancers detected each year, resulting in 330,000 deaths. However, thanks to advancements in AI technology, cancer detection has become more efficient. Convolutional neural networks have been refined and have shown significant improvement in automated cancer detection, as demonstrated in a study .In addition, another researcher used CNNs withconfocal laser endomicroscopy images to diagnose Oral Squamous Cell Carcinoma, resulting in promising results. Early diagnosis is made possible through the use of AI models. Furthermore, AI technology has been used to predict postoperative facial swelling after tooth extraction. A researcher utilized an artificial intelligence model based on ANN to predict postoperative facial swelling with excellent results, which is beneficial for clinicians to forecast treatment prognosis

The clinical potential of AI has been significant in tracing critical anatomic structures through the analysis of patients' radiographic data or diffuse reflectance spectra produced by a laser scalpel. These structures include interdigitated tongue muscles, the mandibular canal, nerves, and the parotid gland. While AI-based segmentation is only slightly different from expert measurement or true anatomic position, it is still substantial for fine structures such as neurovascular canals, which may lead to severe surgical complications. In terms of postoperative rehabilitation, an ML-based voice conversion technique has been used to enhance the speech intelligibility of oral surgical patients by transforming non-audible murmurs of source speakers into the normal speech of target speakers. This technique adapts well to a limited amount of training data and has acquired satisfactory short-time objective intelligibility scores[23]

- **Prevention of Dental Trauma**

Even though dental traumas are a frequent occurrence among toddlers and teenagers and are a typical health issue that dental professionals handle, there has been an increase in their incidence over the past twenty years. Dental injuries are always deemed an emergency and necessitate immediate action to alleviate pain and address teeth displacement or damaged tissues. A comprehensive diagnostic procedure and prompt response from dental professionals can ensure a successful recovery. Empirical evidence confirms that the more meticulous the examination, the more successful the treatment outcome. Furthermore, an appropriate response and in-depth examination, coupled with expertise in traumatology, can help alleviate anxiety or stress and streamline the dental team's operations. Knowledge-based systems (KBS), a practical implementation of AI, is a system that provides valuable support to caregivers.

With the helping hand of AI, a widely known program (XpertRule, Attar, London) can be used to cross-analyze the input data and predict dental injuries with children. With the context given, such information can be further deployed to prevent dental trauma or provide a summary of children’s behavior patterns when active. The prevention can be enhanced by using mouth guards and helmets during sports activities[27]

10.AI in Periodontal Risk Assessment

Periodontitis appears to be one of the most common dental diseases in the general adult population. Every second a person over 50 years of age suffers from this disease and thus is likely to become toothless during their lifetimes. According to the definition, periodontitis starts as a severe gum infection. Still, it develops in a complex inflammatory disease that damages soft tissues, both the tissues anchoring the tooth root in its bone and the gingiva. When the disease progresses, it causes the increase of gingival crevices and the development of periodontal pockets, leading to loss of teeth . In order to prevent complications, AI technology is believed to introduce solutions that might help cure this largely preventable disease. An innovative machine-based learning analysis that included numerous medical and sociodemographic features of the general population showcased that periodontitis, like any chronic condition typical of an older population, bears linkage to a structural risk pattern contrary to belief not rooted in poor oral habits or other relevant stressors. As the database did not contain oral hygiene-related variables such as plaque index, which can make a difference between gingival inflammations caused by gingival inflammation and those not related to oral hygiene, the structural risk pattern could not be predicted at all . The chosen variables included by the algorithm were generally known risk factors such as smoking, female hormones, or age.

The machine learning approach provides a risk score for periodontitis based on personalized characteristics, excluding local factors. AI technology can easily recognize individuals that are likely to develop periodontitis, provided a compound range of variables are deployed, including medical, sociodemographic, or genetic factors. If the machine learning findings are utilized as complementary data that support diagnostics of risk-prone patients, preventive measures may be better tailored to achieve success[24]

11.Impact of AI on the Global Health

AI is expected to revolutionize dentistry in the future, providing a significant improvement in disease detection and treatment. However, the impact of this technology on individuals, systems, and communities is not yet fully understood, especially in low-resource settings.

The use of AI in dentistry has already shown remarkable results in the detection, diagnosis, and treatment of oral diseases. Deep learning, a type of artificial neural network-based machine learning, has enabled accurate interpretation of x-rays, photos, symptoms, and habits, comparable to that of trained practitioners.

In many low- to middle-income countries, the rapid advancements in IT suggest that AI will play a crucial role in global health, providing solutions to emerging challenges and ensuring sustainable development in the health and prevention fields

There is a current debate on the use of AI in healthcare, with concerns about ethical decision-making and the potential impact on traditional procedures. Low- and middle-income countries have recently implemented AI interventions, primarily targeting infectious diseases like tuberculosis and malaria. The concept of AI varies in types and applications. However, numerous forms of machine learning or signal processing are predominantly applied, frequently in synergy with other methods, principally signal-to-process. It is reported that there are four AI-driven health interventions, classified in separate categories:

(1) Diagnostics,

(2) patient mortality risk assessment,

(3) disease outbreak prediction and surveillance, and

(4) health policy and planning.

Despite the growing interest in AI-based interventions in global health, the literature often overlooks important ethical, administrative, and practical considerations that are crucial for the widespread implementation of AI in this field.

Although the use of AI in healthcare interventions is a relatively new concept, it holds great promise for achieving positive outcomes in low- and middle-income countries. However, as noted by many researchers, there is a pressing need for comprehensive methodological guidelines that take into account ethical limitations and concerns in order to define the scope, function, and goals of AI approaches to the global healthcare system

AI-based interventions in oral public health are typically categorized into three domains. The first domain involves AI-driven tools that can be used on smartphones or portable devices by non-specialist community health workers (CHWs) to address traditional oral diseases in off-site locations.According to a report that CHWs follow are AI recommendations to triage patients and identify those in need of immediate treatment. This category of application also includes the use of AI for diagnosing oral and labial cancer based on photographic images and peripheral blood samples. The development of pocket diagnostic hardware such as ultrasound probes and microscopes hold promise for rapid improvements in this domain. Finally, ubiquitous smartphones allow patients to use AI to design their nutrition and daily routines.

The technology will also enable symptoms self-assessment and cover the advisory aspect during pregnancy or recovery phases, eventually allowing patients to monitor their health, thus facilitating the operation of the health system[26]

A major limitation, as the models may not be applicable to low- and middle-income countries due to differences in disease prevalence and healthcare systems. Nonetheless, the potential benefits of AI in healthcare are vast, and with further development and validation, AI could revolutionize the way healthcare is delivered and improve patient outcomes hampering the full implementation of AI. The models are limited to several elements, such as some disease demographics, etc.

Nonuniform and unsteady statistical data analysis and quality control result in inconsistencies that allow for errors producing models that prevent establishing generalizations, etc. Apprehension exists regarding certain ethical concerns, e.g., patients' data privacy breach as a third entity is introduced into the patient-doctor relationship. From the aspect of the regulation, possible medical malpractices and liabilities arising from newly established algorithmic decision-making are yet to be formulated. Given that almost all AI tools in health care refer to single-task applications, these are not anticipated to fully substitute health professionals, which helps to lower the expectations

Introducing AI tools in resource-limited environments poses challenges. Given the diverse needs, disease specificities, as well as those of demographics and standards across low and middle-income countries, specific AI application cases with the most prominent influence need to be identified and acknowledged accordingly

Context-specific training and validation data are necessary, along with solutions required to be context-specific. The latter primarily refers to the requirement that an automated system be prevented from recommending treatments inaccessible locally or those that are unlawfully expensive. What is more, human factors need to be observed, i.e., competencies, education, and digital literacy of end users. The behavioral aspect relative to raising awareness and confidence in AIsystems should also be in focus, as this will let users recognize limitations and accurately read the results. Availability of devices supporting AI applications, e.g., continuous, and steady, internet, electricity, etc. also need to be assessed. Diverse digital initiatives have also enhanced the quality of healthcare services in low- and middle-income countries. These include healthcare practices that support technologies like eHealth and telehealth platforms (telecommunication/mobile health (mHealth)). The most effective practices for scaling these digital initiatives in have been established based on practical experiences. These endeavors could create a learning environment for related digital artificial intelligence (AI) applications. However, there are various challenging factors, such as limited funding and inappropriate and unreliable infrastructure, that may hinder the fast and proper implementation of AI applications. Integration opportunities should also be considered. For example, a suitable mHealth application designed for patient-doctor distance communication can be upgraded with an AI chatbot to triage patients before their consultation.

Some concerns have been raised about the value of implementing AI in since it primarily requires investments in basic infrastructure. AI-governed interventions should not be evaluated in isolation, nor should they be attributed to cure-all capabilities. Although significant initial investments may be required, the marginal cost of providing an existing AI software service to one more user is minimal, making it economically scalable. Existing digital technologies may also provide proper utilization of AI applications. Finally, the incentive for AI in healthcare interventions within should be managed entirely by local stakeholders responsible for funding. At present, AI literacy is assumed in global health educational programs, a trend that will undoubtedly continue in the future, aimed at raising awareness of its capabilities and possible drawbacks. Promoting the AI concept locally will be of utmost importance, with the ability to be promoted through free educational online programs. The incorporation of AI will also need to rely on regulatory frameworks, which need to be adjusted to allow for the effective implementation of AI

Two crucial aspects concept, e.g., the training of local health professionals may be extended to involve screening and diagnosing noncommunicable diseases (NCDs) to be identified to introduce AI into are investments and obtaining data on the impact of AI solutions. As the existing tensions between social groups (the rich-the poor) have been additionally increased by an uneven distribution of access to digital technologies, AI could be a mediator capable of mitigating the differences as a socially responsible technology available to all social classes [25]

12.Using Machine Learning to Detect Abnormalities

AI-powered clinical decision support systems can effectively provide valuable data to medical professionals, thereby enhancing health outcomes for both individual patients and the broader population. Ultimately, AI has demonstrated its usefulness in delivering high-precision medical images. Research has shown that artificial neural networks powered by AI can identify signs of oral cancer and other conditions with the same accuracy and reliability as human radiologists. Furthermore, AI can assist dentists in identifying early signs of disease[28]

13.Automated Evidence Synthesis Enabled by Machine Learning

The traditional process of inputting structured health information into the system has been time-consuming. However, the introduction of voice recognition and the use of AI programs to classify and extract information from scanned documents has significantly streamlined the process. It is worth noting that the interactive nature of AI allows healthcare professionals to process more data more efficiently and reliably than human assistant[29]

14.Management of Dental Clinics

AI's role as a critical component in improving public oral health and significance is best demonstrated in the management and general operations of dental clinics. One such aspect is scheduling patient appointments, which can benefit from newly implemented AI-powered systems. assistants can be easily trained to perform such tasks more efficiently and productively.

Smart scheduling of appointments using AI has revolutionized doctor-patient communication. The program uses proprietary algorithms to systematically contact patients, identify their appointment preferences, and match them with available slots. The scheduling process is automated and patients can be contacted via voice, text, or video. The AI system also helps in launching marketing campaigns for new patients. The system can track and optimize patient appointments, proactively schedule unfinished treatment, and initiate marketing campaigns based on profit maximization algorithms. The system uses machine learning programs to interface with dental practice software and handle simple patient queries. Complex queries are directed to the practitioner for further processing. The system can mine data and detect periods of decreased productivity to help determine the most effective marketing campaign.

Deep learning techniques are used to search patient records for the most profitable patient treatment. This saves time for assistants who can act more readily before the actual appointment if there is an emergency with a patient. AI also supports dental health-care professionals in terms of any relevant medical history or allergies that the patient may have. Patients who are on tobacco or smoking cessation programs can utilize AI to set up necessary reminders.

In rare instances when a physician is unavailable, AI can provide assistance by storing diverse patient health information. In addition to documentation and scientific coding, AI can retain patient databases, track patient orders, monitor health conditions, and implement preventive measures.

With the abundance of big data, such as electronic health records, digital radiographs, and longitudinal follow-up data, a reliable source for training AI systems can be established. A better understanding of a patient's condition, based on vast data, can significantly improve predictions. The AI scientific data library can learn from the scientific database and keep itself updated with current literature knowledge in the field.

AI software in dental clinics can create a comprehensive virtual database for each patient that is easily accessible. Voice recognition and interactive interfaces enable the software to assist dentists in performing various tasks. The AI system can retrieve all necessary data from the database and present it to the dentist more efficiently than a human, making dental interventions more reliable. The AI system can also be trained to perform other functions, such as integrating with imaging systems like MRI and CBCT to identify slight deviations from normalcy that may have gone unnoticed by the human eye.

However, AI in the dental field is still in its infancy and cannot replace human skills and competence. AI can complement dental operations and raise awareness of oral and maxillofacial diseases while encouraging patients to seek preliminary treatment. Although AI has produced staggering solutions that may change dental procedures in the future, the general concern remains about how and to what extent AI can be integrated into practice. AI cannot act as a complete substitute for a dentist, as clinical trials involve more than diagnoses; they also include correlating with clinical findings. and imparting personalized patient care. Although AI can be utilized as a handy and quick solution in many ways, some of which have been mentioned in the text, the final decisions need to be made exclusively by dentists, as dentistry is a multidisciplinary approach that needs to consider numerous specific elements related to human health [29]

15. Artificial Intelligence and the Monetary Facet of Dentistry.

The financial dimension of dental care is another area of dentistry where AI technology proves to be highly advantageous. With the aid of dental AI, the dental process becomes more transparent for both the payer and the provider when dealing with the same documentation. In other words, dental practitioners who incorporate the use of AI in their clinical workflow will be able to determine if there is proper, evidence-based documentation and whether it conforms to the insurer's policies. For instance, if there is a need to capture an image of a broken cusp when it is not visible in a radiograph, AI systems can prompt the need for a picture. This way, misinterpretations of clinical guidelines are minimized, and care providers become more aware of the objective measures used by payers. Of course, clinicians who review claims must be consistent when applying standards. Inconsistency in claims review usually occurs due to two factors: inter-clinician variability and sampling of claims for review. As for inter-clinician variability, it is expected that the more clinicians review the same claim or radiograph, the more diverse viewpoints we get. Various providers may suggest different treatment plans for a single patient. Different perspectives of the same situation may arise due to previous skills or training, experience, or even fatigue of the dental provider. As research suggests, AI can provide reliable and accurate measurements that support or recommend each claim without unnecessary subjective estimates, which may vary (i.e., whether the amount of missing tooth structure is 40% or 50%). In such cases, dental consultants will consider outputs from the AI analysis before making the final decision.

Recent studies indicate that AI-enhanced claims review can significantly reduce costs. This is because every time a claim is resubmitted or an appeal is filed, it incurs additional costs for both parties. Furthermore, inconsistency in claims adjudication can arise due to a shortage of dental consultants, resulting in only a small number of claims being processed. In such cases, even if two separate benefit claims for the same diagnosis are submitted, payment will only be made for one share. This is because a denial of benefit payment may have been warranted in both cases, but the approved claim was not reviewed clinically and therefore benefited by default. To avoid such situations and prevent provider and patient dissatisfaction, AI support can be used to process all reviewable claims and identify those that do not meet the required standards for approval. With AI assistance, the claims review process can be conducted consistently and efficiently.

The utilization of AI in reviewing claims has specific advantages for patients. The system's transparency will be improved, and there will be fewer patient appeals and surprise denials. With regular use, the AI system will ensure the validity and confidence of patients in their dental benefits and treatment plans. As a result, reviewing claims will be more efficient, leading to faster reimbursement and reduced administrative costs for payers. This, in turn, will result in slower growth of premiums for patients and employers

Another financial benefit of the AI system in dental clinics is the ability to provide instant predetermination. Nowadays, many dental payers offer predeterminations or pre-estimates for costly procedures. Payers prefer predetermination to identify contractual limitations or exclusions that apply to a proposed treatment plan. Although some plan details can be found on payer websites, an additional clinical review is needed, which increases turnaround times for payers to 2 or 3 weeks. Dental AI is expected to revolutionize this process soon.AI adoption has already commenced for internal claims review and in provider offices. As the main goal for providers and payers is to provide the best experience for patients, and AI potentially brings more clarity and reliability for patients, all parties involved in the process will rely on AI solutions. Finally, the AI paradigm reduces financial uncertainty for patients and helps general dentistry find solutions to resolving delays that can discourage medically necessary treatments[30]

16. The Implementation of Artificial Intelligence in the Recent Coronavirus (COVID-19) Epidemic.

In the present times, the utilization of the AI system in the emerging corona-virus (COVID-19) situation has emphasized its potential for efficient control of public health during unforeseen disease outbreaks. In situations where there is an urgent risk posed by sudden disease outbreaks, the AI principle can guarantee a prompt and protected decision-making procedure, owing to its ability to scrutinize the extensive data.

The prevention and control of infection (PCI) program considers hand hygiene to be a crucial element. The use of technology in hand hygiene has the potential to enhance and modify PCI procedures by introducing innovative guidance methods and assessments. The Sure Wash system is a commonly used interactive booth that incorporates augmented reality-powered monitoring to instruct and measure hygiene techniques, leading to improved hygiene performance.

The booth's portability allows healthcare personnel to use it as and when required, receiving immediate individual feedback on the quality of their hygiene practice. Recently, the system has also been made available through a smartphone application for similar purposes. A trial of an integrated digital hand hygiene framework that included the SureWash system, a hand hygiene auditing tool, and an activity monitoring system demonstrated the feasibility of using artificial intelligence without disrupting clinical workflow.[31]