APPLICATION OF ARTIFICIAL INTELLIGENCE IN DENTISTRY

GENERAL DENTISTRY

The advantage of AI lies in the fact that machines can be trained to analyse 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 fewer human resources, fewer errors, and greater precision than humans. They assist in scheduling appointments, managing insurance and paperwork, as well as assisting in clinical diagnosis and treatment planning. Additionally, they help notify 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 advantageous.

AI has now become an essential part of our daily lives, with the emergence of Siri and Alexa allowing us to use voice commands. The dental practice has also been upgraded, 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 conducted with a reduced risk of cross-contamination during treatments. Thus, a comprehensive virtual database of the patient can be created, which will greatly assist in providing the best possible treatment for the patient.

Diagnosis, Treatment 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 needed to analyse the input data and generate a personalized output. Artificial intelligence (AI) allows for a more systematic and organized collection of patient data, reduces repetitive tasks, encourages research and development, and provides a promising alternative to a more collaborative healthcare system. AI focuses on constructing a strong system for each process by extracting relevant data from a vast repository of medical records to assist dental professionals in making informed choices and help patients understand their condition and prognosis.

Clinical Decision Support Systems (CDSS) were created to handle the increasing amount of patient data over time and analyse it using an integrated clinical database, thereby aiding dental professionals in making decisions regarding diagnosis, prevention, treatment, and prognosis of the condition. The CDSS operates by categorizing a patient with a toothache based on their caries risk assessment, using a brief questionnaire that includes their most recent 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 enhancing efficiency.

Techniques of AI in the field of orthodontics.

The future of orthodontics is no longer dependent on appliances, but rather on AI. Recently, AI has been utilized to analyse radiographs and photographs to assist in orthodontic diagnosis, treatment planning, and monitoring treatment progress. Additionally, intraoral scanners and cameras are replacing dental impressions with digital impressions, which are input into algorithms and AI software to forecast tooth movements and treatment results. By combining the latest technologies with personalized aligner-based orthodontics, case acceptance can be enhanced.

To achieve successful orthodontic treatment, precise diagnosis, treatment planning, and prognosis prediction are crucial. AI technology has been employed to determine the necessity of extractions prior to orthodontic treatment. A study conducted by a researcher utilized an artificial neural network (ANN) model to analyse lateral cephalometric radiographs and accurately predict the need for extractions. Another study demonstrated 92% accuracy in using an AI expert system to decide on permanent tooth extraction. These findings suggest that AI models can be effective and precise in predicting the need for extraction and can be utilized as a tool in clinical practice. Another researcher demonstrated high precision in an AI model based on Bayesian network (BN) for assessing the need for orthodontic treatment.

AI can also be utilized for assessing treatment needs and scoring outcomes in pediatric orthodontics. Bayesian network and support vector machines (SVM) have been employed to diagnose orthodontic treatment needs and assess the time taken for laypersons to view patients, respectively. Convolutional neural networks (CNNs) have been used to characterize specific facial traits for attractiveness scoring and estimation of apparent age. The introduction of AI in pediatric orthodontics can provide an objective and reproducible interpretation of facial appearance.

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. Personalized 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 .

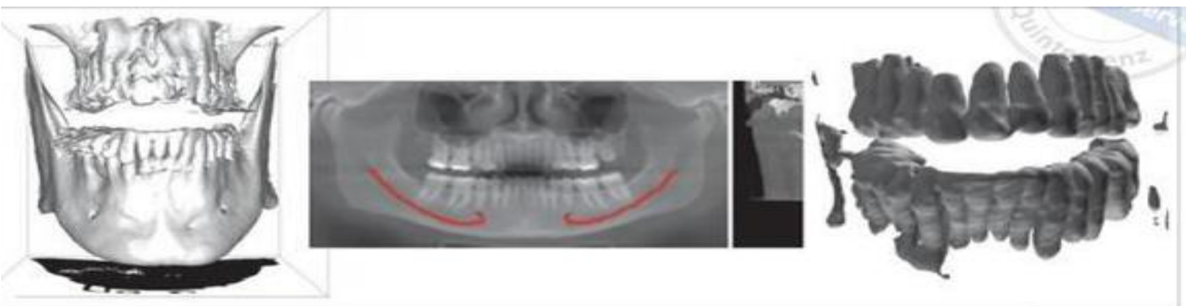

Fig: Automatic structure segmentation, annotation and data conversation

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

By utilizing CBCT scanning, artificial intelligence can precisely 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, assisting dentists in decision-making processes to solve problems

Diagnostic imaging such as CT scans, MRI scans, and periapical radiographs can provide valuable input for augmented reality (AR) information. This allows dentists to acquire crucial information about root canal anatomy while maintaining their focus on the operating field, unlike traditional 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.

Endodontics and AI

Dental professionals who have been working for long periods may experience tiredness and fatigue, leading to potential oversight of tooth decay during examinations. The integration of AI software can offer significant advantages in assisting dentists to identify cavities on X-rays. According to researchers, bitewing intraoral X-rays are effective in detecting tooth decay in its early stages, increasing awareness of oral health conditions and enabling preventive treatments.

AI technology can accurately locate tooth areas prone to cavities and complex peri-apical pathologies, define lesion boundaries precisely, and distinguish between different diseases. Logicon Caries Detector can detect and characterize proximal cavities, analyse the lifespan of dental restorations, and locate minor apical foramen (AF) for more precise determination of working length.

Endodontic procedures require high accuracy, 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 distraction from the operating site.

In-vitro testing has been conducted on micro-robots with catalytic abilities for the elimination 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 common in the fields of cariology and endodontic diagnostics. DL can automatically segment lesions in X-rays 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 cavities 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 raises questions about 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 beyond human vision.

Early identification of periapical lesions can help prevent complications and enhance patient outcomes. According to one investigation, the CNN that underwent training and validation on 2902 OPGs outperformed 14 out of 24 oral maxillofacial surgeons with varying levels of professional experience. In a different study involving 85 OPGs, the ML model achieved a sensitivity of 0.65 and a specificity of 0.87. A neural network specifically designed for image segmentation, which underwent training and validation on 20 CBCTs, achieved a sensitivity of 0.93 and a specificity of 0.88. A neural network was developed to identify vertical root fractures (VRF) in premolar teeth that were treated with or without endodontics, utilizing periapical radiographs and CBCTs. The detection of VRF on CBCTs significantly outperformed periapical imaging, as it encountered challenges in ensuring that the beam was perpendicular to the fracture in periapical imaging, resulting in a sensitivity and specificity of 93.3% and 100% respectively.

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

Endo Micro mechanoid

The effectiveness of root canal treatment depends greatly on the clinician's understanding, skill, ability to feel, and decision-making. Regrettably, mistakes in root canal procedures such as canal blockage, hole formation, removal of the natural opening at the tip, and excessive use of instruments beyond the root tip may happen. To improve the standard of root canal treatment and decrease the chance of mistakes made by humans, it is crucial to introduce advanced technology and computer-assisted engineering into endodontic practice.

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-operated device will be attached to multiple teeth in the patient's mouth. The miniaturized device or android will carry out the automatic drilling, sanitizing, and sealing of the root canal with internet-based supervision and smart management. All other sub-project findings will be integrated into this robotic procedure.

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 foundation of the device is shaped like a saddle and will rest on a pair of reference brackets and the teeth. Before capturing X-rays and attaching the device, the brackets, 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 be used as support. The pair of brackets serve as three radiopaque reference points to align the device, thereby establishing a coordinate system. Once the device is placed on the reference brackets, the foundation will remain stationary in relation to the patient's teeth, regardless of any movements made by the patient's head or jaw. The device 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 device can be used for multiple purposes and can accommodate various endodontic tools and accessories. A quick tool change mechanism, utilizing 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 device.

Mini Sensors & Actuators

The design of this device also includes sensors for smart monitoring of the treatment process. Due to the small size of the sensors, they can be made using a technique called surface micro-engineering to create silicon-on-insulator (SOI) wafers, which will be integrated into the miniaturized robot. The robot's five axes (five degrees of freedom) and the on/off spindle are operated by six micro-actuators. Each actuator is independently controlled by a digital numerical control (NC) controller. The controller must promptly respond to the sensor signal, typically within a few milliseconds. Additional features include a cleaning nozzle for irrigation, a suction cup for removing chips and waste fluid, and/or optical fibres for illumination, imaging, and observation. While a manual remote control for clinicians will be available, the ultimate goal is to achieve fully automatic operation with the assistance of a computerized treatment planning and control system, ensuring a flawless procedure. An interface system will be provided to allow clinicians to interact with the machine control. The computer-aided treatment planning system, 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 robot's movements 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 plan the order of actions using different tools and motion control parameters to complete the preparation of the root canal. An optimization algorithm will be integrated into this automated prescription software to minimize removal of tooth structure and prevent unnecessary tool changing.

Advanced Endodontic Technology Development is focused on creating a micro robot for endodontic procedures that offers a less invasive approach to root canal therapy compared to traditional methods of access. This approach involves automated access and canal preparation during endodontic treatment, reducing the chance of human error.

In the field of Cariology and Endodontics, machine learning algorithms like SVM, RF, and k-nearest neighbours were used to develop predictive models for identifying individuals at risk of tooth surface loss and root caries. SVM showed the highest accuracy of 97% and sensitivity of 99.6% by analysing patient data such as demographics, nutrition, lifestyle, and clinical information. Additionally, by using 83 features from the "Endodontic Case Difficulty Assessment Form" by the American Association of Endodontists, SVM and ANN achieved over 90% accuracy in predicting the level of difficulty of cases requiring root canal treatment.

This demonstrates the potential of machine learning to enhance the decision-making abilities of general dental practitioners when referring patients to endodontists.

Currently, the primary focus of machine learning research is on identifying early carious lesions in dental images. One machine learning algorithm examined 3686 bitewing radiographs and performed semantic segmentation to classify caries pixel by pixel. In detecting initial lesions, the CNN model outperformed seven dentists with clinical experience ranging from 3 to 14 years and was more effective than most experienced dentists. Another CNN model was trained and tested on 3000 cropped periapical images to classify caries. This model showed 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 used for semantic segmentation to detect occlusal and proximal carious lesions in 185 DIAGNO CAM near-infrared transillumination images. The dental experts and the machine learning model only agreed on 49% of the areas marked as caries. However, DIAGNO CAM is not widely available in dental practices, and bitewing radiographs have been shown to have the highest sensitivity and specificity for detecting occlusal and proximal caries.

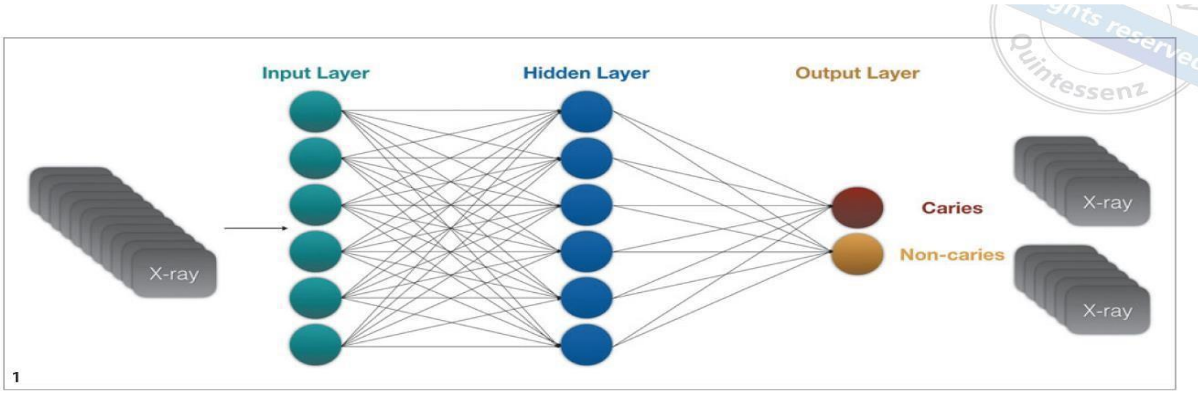

Fig 1 The example of deep learning with the application of detecting caries using radiographs. The radiographs will be imported to the software as the input layer. Through multiple "hidden layers," the algorithms will classify imported radiographs as "caries" or "non-caries" based on the AI training.

Detecting individuals at elevated risk of disease progression at an early stage can aid in preventing or intervening in the disease process. The support vector machine (SVM) model displayed outstanding performance with an area under the curve (AUC) of 0.997, 99.6% sensitivity, and 94.3% specificity.

Furthermore, while age was understandably the most important predictor of root caries risk, the machine learning (ML) model identified unexpected variables such as computer usage, television viewing hours, and sunscreen application. Although ML uncovers unforeseen connections, these variables are not the underlying causes of root caries. However, they do provide insight into individual lifestyle factors that can be integrated into a patient-centred care approach for diagnosing and planning treatment for root caries. By analysing extensive datasets that may not be otherwise considered, ML models can serve as a complementary tool to the clinician's intuition in predicting future caries risk.

Preventive Dentistry

In addition to its utilization in dental diagnosis, therapy, and management, machine intelligence has demonstrated immense potential in preventing and monitoring infections.

The surveillance of healthcare-associated 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 vulnerable areas so that practitioners can implement appropriate preventive measures and take action accordingly. An HAI surveillance program utilizes databases from various sources to assess emerging disease outbreaks and analyse patterns and indicators in detail. In other words, an HAI program measures the occurrence of HAIs and evaluates the seriousness 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 hospital-acquired outbreaks of methicillin-resistant Staphylococcus aureus and influenza. Similarly, EHRs that utilize machine learning applications have proven to be invaluable in predicting the risks of hospital-acquired Clostridioides difficile infection (CDI), thus preventing or mitigating severe complications. The advantage of the machine learning method over traditional CDI risk grouping is that the AI program analyses existing risk factors and utilizes a wide range of variables within the EHR. Therefore, this technology can create various models to cater to the specific needs of either patient or caregiver populations. As a patient's CDI risk is likely to change during their hospital 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 empirical evidence in clinical trials and other relevant research studies focused on HAI. However, it is evident that it has strong potential for enhancing 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 adequately trained to use it. Nevertheless, overcoming these challenges will enable us to harness the potential of AI.

AI Algorithms and Nutrition in Preventive Dentistry

Observing the nutritional behaviour of sufferers is a essential factor of preventive dentistry. The sort of meals we eat and the way regularly we devour it are without delay related to oral diseases, especially cavities. Advanced AI algorithms are step by step being applied in medical vitamins studies, that is implemented in assisting nutritional activities, assessing dangers associated with meals-associated dental diseases, and tracking popular nutrient behaviour.

AI has end up sizable in prophylaxis via nutritional evaluation cellular applications. Researchers suggested a a success layout of an digital photographic approach and photograph processing algorithms that estimate meals intake. Researchers advanced cross FOODTM, an synthetic nutritional assessment machine primarily based totally on AI that calls for enter statistics via pattern pix taken with the aid of using a smartphone. This machine calculates the calorie and macronutrient content material of a meal, offering a dependable nutritional evaluation. Similarly, Researchers added Ontology for Nutritional Epidemiology (ONE) as an actual device for less difficult integration, visibility, and connectedness of study's findings in dietary epidemiology. This study gives a greater goal nutritional evaluation.

Researchers designed a nutritional assessment machine primarily based totally on a selected neural community that calculates meals volume. They applied a fixed of visible facts to increase a neural community the use of the deep gaining knowledge of approach. Another organization of researchers approximated meals power primarily based totally on pics and the generative hostile community (GAN) structure from cellular tele cell smartphone pics of meals quantities over per week with a pattern of forty-five respondents

As AI technology continues to advance, it is increasingly being used to evaluate 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 sophisticated algorithms to be developed. Such advancements could be particularly important in addressing the global obesity epidemic. For instance, researchers have already utilized the Internet of Things (IoT) approach to create a monitoring system that tracks personal activities through sensors on a smart-log patch. By analysing this data using a Bayesian deep learning network (EC- BDLN), they obtained valuable insights into cardio-metabolic caries risk factors in the general population. Similarly, researchers have explored the use of machine learning algorithms like support vector machine (SVM), neural network, and k-nearest neighbour (kNN) computations to identify observable characteristics in women's physique.

Despite these promising advancements, there is still a significant lack of more advanced AI algorithms that could be used for similar purposes. One potential solution to this issue could 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 challenges of future research can we fully unlock the potential of AI technology in the field of nutrition.

Dental Caries Prevention

Recent research has indicated that genetic elements play a substantial role in the development of tooth decay. Consequently, there is a necessity to create novel models for predicting the risk of tooth decay (CRPMs) that consider both genetic and environmental factors in order to accurately anticipate the likelihood of tooth decay. According to recent studies, tooth decay was the most prevalent chronic ailment worldwide in 2016. The treatment of tooth decay has also become a significant financial burden, with global costs reaching 540 billion dollars in 2015.

Therefore, it is crucial to take immediate action to prevent tooth decay risks. Research has shown that there has been a shift in the occurrence of tooth decay, with adolescents now being the most affected demographic. Scholars have recommended that more attention should be given to individuals who are at risk of developing tooth decay in order to prevent and control the disease. AI-based tools and applications can be utilized to implement risk prediction models for early detection and accurate examinations in at-risk adolescents.

CRPMs are non-invasive treatment approaches that have greatly improved patient care. Currently, there are 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 necessary for precise prediction of tooth decay risk. and behavioural factors, including plaque index, the number of Streptococcus mutans and Lactobacillus, saliva flow, and salivary buffer capacity. There is a consensus that the Cariogram appears to be the most advanced and accurate of all the mentioned CRPMs for certain tests. However, it fails to demonstrate its effectiveness in predicting tooth decay. As demonstrated by Researchers, Cariogram exhibits varying sensitivity ranges, ranging from 41.0% to 75.0%, while specificity ranged from 65.8% to 88.0%.

The development of tooth decay is the result of a complex interaction between genetic and environmental risk factors. Environmental factors such as inadequate oral hygiene, excessive sugar consumption, dental plaque, and saliva quality are commonly identified as determinants of tooth decay risk. However, genetic factors also play a significant role, with genetic risk scores accounting for approximately 49.1% to 62.7% of the variation. Tooth decay risk is a distinct genetic characteristic that can be influenced by various other factors, including dietary habits, immune system function, saliva composition, taste.

This suggests that it is crucial to investigate and study CRPMs with practical applications related to both factors so that the prediction of caries risk can be conducted with greater precision. Researchers introduced 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 similar 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

With approximately 1.8 billion new instances occurring annually worldwide, early childhood caries (ECC) is a persistent childhood ailment. AI can provide innovative and reliable 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.

Oral Hygiene

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

Normally, oral hygiene behaviour 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 burdensome, particularly if individuals do not have regular access to dental services. To gain a better understanding of the relationship between oral hygiene behaviour 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-centered care. This would give a digitally involved patient more control over their oral health and consequently make them more engaged.

The device can track missed areas and offer personalized suggestions regarding oral care, thanks to artificial intelligence (AI) and machine learning algorithms. User application of excessive pressure and teeth that require more attention and percentage of brushed surface are all displayed on a tooth map. Suppose the person applies too much pressure, it is possible to cause gingival damage; therefore, it’s important to prevent that. Thanks to AI-powered examinations, patients have no difficulty achieving a thorough and accurate mouth cleaning. This includes improving their technique, completion of brushing on missed surfaces, and maintaining a gentle pressure. In no time, they will have a perfect oral hygiene routine without missing a tooth. Serious tooth decay complications can be prevented by incorporating smart toothbrushes into a hygiene program. One issue that needs to be directly addressed and further investigated for the implementation of these devices is their slightly higher price compared to standard toothbrushes. They usually have a replaceable brush head.

Oral and maxillofacial surgery and AI

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

The clinical potential of AI has been significant in tracing crucial anatomical structures through the analysis of patients' radiographic data or diffuse reflectance spectra generated 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 anatomical position, it is still substantial for intricate structures such as neurovascular canals, which may lead to severe surgical complications. In terms of postoperative rehabilitation, a machine learning (ML)-based voice conversion technique has been utilized to enhance the speech intelligibility of oral surgical patients by transforming inaudible murmurs of source speakers into the normal speech of target speakers. This technique adapts well to a limited amount of training data and has achieved satisfactory short-time objective intelligibility scores.

Prevention of Dental Trauma

Despite being a common occurrence among young children and adolescents, dental injuries have become more prevalent in the last two decades. These incidents require immediate attention from dental professionals to alleviate pain and address tooth displacement or tissue damage. A thorough diagnostic process and quick response from dental experts can lead to a successful recovery. Research shows that the more meticulous the examination, the better the treatment outcome. Additionally, a prompt and thorough examination, combined with expertise in traumatology, can help reduce anxiety and streamline the dental team's workflow. Knowledge-based systems (KBS), which implement artificial intelligence (AI), offer valuable support to caregivers.

With the assistance of AI, a well-known program (XpertRule, Attar, London) can analyse input data and predict dental injuries in children. This information can be used to prevent dental trauma or provide insights into children's behaviour patterns during physical activity. Prevention methods can be enhanced by using mouth guards and helmets during sports activities

AI in Periodontium Risk Assessment

Periodontitis is believed to be one of the most prevalent dental diseases in the general adult population. Every other person above 50 years old is affected by this condition and therefore has a high chance of losing their teeth in their lifetime. According to the definition, periodontitis initially starts as a severe gum infection. However, it progresses into a complex inflammatory disease that harms the soft tissues, including the tissues that hold the tooth root in its bone and the gum tissue. As the disease advances, it leads to the enlargement of gum crevices and the formation of periodontal pockets, resulting in tooth loss. To prevent complications, AI technology is thought to introduce solutions that could potentially treat this largely preventable disease. A groundbreaking machine-based learning analysis, which considered various medical and sociodemographic features of the general population, demonstrated that periodontitis, like any chronic condition commonly found in older individuals, is associated with a risk pattern that is not caused by poor oral habits or other relevant stress factors, contrary to popular belief. Since the database did not include variables related to oral hygiene, such as plaque index, which can differentiate between gum inflammations caused by poor oral hygiene and those unrelated to it, the risk pattern could not be accurately predicted. The selected variables incorporated by the algorithm were generally recognized risk factors like smoking, female hormones, and age. The machine learning approach generates a risk score for periodontitis based on individual characteristics, excluding local factors. AI technology can easily identify individuals who are likely to develop periodontitis by utilizing a comprehensive range of variables, including medical, sociodemographic, and genetic factors. If the machine learning findings are used as additional data to support the diagnosis of high-risk patients, preventive measures can be more effectively tailored to achieve successful outcomes.

Impact of AI on the Global Health

AI is predicted to transform the field of dentistry in the future, bringing about significant advancements in the detection and treatment of diseases. However, the full impact of this technology on individuals, systems, and communities, particularly in low-resource settings, is not yet fully understood. The utilization of AI in dentistry has already demonstrated impressive outcomes in identifying, diagnosing, and treating oral diseases. Deep learning, a form of machine learning based on artificial neural networks, has enabled accurate analysis of x-rays, photographs, symptoms, and habits, comparable to that of trained professionals.

In many countries with low to medium income levels, the rapid progress in information technology suggests that AI will play a critical role in global healthcare, offering solutions to emerging challenges and promoting sustainable development in the fields of health and prevention.

There is an ongoing discussion regarding the use of AI in healthcare, with concerns regarding ethical decision-making and the potential impact on traditional procedures. Low and middle-income countries have recently implemented AI interventions, primarily focusing on infectious diseases such as tuberculosis and malaria. The concept of AI encompasses various types and applications.

However, a wide range of machine learning techniques or signal processing methods are predominantly employed, often in combination with other approaches, particularly 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 increasing interest in AI-based interventions in global health, the literature often overlooks important moral, managerial, and practical considerations that are essential for the widespread implementation of AI in this field.

While the utilization of AI in healthcare interventions is a relatively new idea, it holds great potential for achieving positive outcomes in low- and middle-income countries. However, as highlighted by many researchers, there is an urgent need for comprehensive methodological guidelines that take into account moral 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 commonly divided into three categories. The first category involves AI-powered tools that can be utilized 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, CHWs follow AI suggestions to prioritize 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 compact diagnostic hardware such as ultrasound probes and microscopes hold promise for rapid advancements in this domain. Lastly, ubiquitous smartphones enable patients to utilize AI to plan their nutrition and daily routines.

The technology will also enable self-assessment of symptoms and provide guidance during pregnancy or recovery phases, ultimately allowing patients to monitor their health, thus facilitating the functioning of the health system.

A major limitation is that the models may not be applicable to low- and middle-income countries due to variations in disease prevalence and healthcare systems. Nevertheless, the potential benefits of AI in healthcare are immense, and with further development and validation, AI could revolutionize the way healthcare is delivered and improve patient outcomes hindering the full implementation of AI. The models are limited to certain elements, such as specific disease demographics, etc.

Inconsistent and unreliable statistical data analysis and quality control lead to discrepancies that allow for errors in creating models that hinder the establishment of generalizations, etc. Concerns exist regarding certain ethical issues, such as the breach of patients' data privacy as a third party is introduced into the patient-doctor relationship. From a regulatory standpoint, potential medical malpractices and liabilities arising from newly established algorithmic decision-making are yet to be defined. Considering that almost all AI tools in healthcare pertain to single-task applications, they are not expected to completely replace healthcare professionals, which helps to manage expectations.

Domain-specific training and validation data are essential, along with context-specific solutions. The latter primarily refers to the requirement that an automated system be prevented from recommending treatments inaccessible locally or those that are unlawfully costly. Furthermore, human factors need to be observed, such as competencies, education, and digital literacy of end users. The behavioural aspect concerning raising awareness and confidence in AI systems should also be emphasized, as this will enable users to recognize limitations and interpret the results accurately. Availability of devices supporting AI applications, such as uninterrupted and stable internet, electricity, etc., also need to be evaluated. Various digital initiatives have also improved 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 expanding these digital initiatives have been established based on practical experiences. These efforts could create a learning environment for related digital artificial intelligence (AI) applications. However, there are several challenging factors, such as limited funding and inadequate and unreliable infrastructure, that may impede the rapid and proper implementation of AI applications. Integration opportunities should also be considered. For instance, a suitable mHealth application designed for patient-doctor distance communication can be enhanced with an AI chatbot to assess patients before their consultation.

Some concerns have been raised about the value of implementing AI in healthcare since it primarily requires investments in basic infrastructure. AI-driven interventions should not be evaluated in isolation, nor should they be seen as a cure-all solution. Although significant initial investments may be necessary, the additional cost of providing an existing AI software service to one more user is minimal, making it economically scalable. Existing digital technologies can also facilitate the effective use of AI applications. Lastly, the promotion of AI in healthcare interventions within a specific context should be managed entirely by local stakeholders responsible for funding. Currently, 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 potential drawbacks. Promoting the concept of AI locally will be of utmost importance and can be achieved through free educational online programs. The incorporation of AI will also rely on regulatory frameworks, which need to be adjusted to facilitate the effective implementation of AI.

Two crucial aspects to consider when introducing AI into a specific context are investments and obtaining data on the impact of AI solutions.

Using AI 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

Automated Evidence Synthesis Enabled by Machine Learning

The customary method of entering organized health data into the system has been a lengthy process. Nevertheless, the implementation of speech recognition and the utilization of artificial intelligence (AI) software to categorize and extract information from scanned papers has greatly simplified the process. It is important to mention that the interactive characteristic of AI enables healthcare experts to handle a greater amount of data with greater efficiency and dependability compared to a human assistant.

Management of Dental Clinics

The role of AI as a crucial element in enhancing public oral health and importance is most effectively demonstrated in the management and overall functioning of dental clinics. One such aspect is the scheduling of patient appointments, which can benefit from newly implemented AI-driven systems. AI assistants can be easily trained to carry out such tasks with greater efficiency and productivity.

Intelligent appointment scheduling using AI has transformed the communication between doctors and patients. The program utilizes specialized algorithms to systematically reach out to patients, identify their appointment preferences, and match them with available time slots. The scheduling process is automated, and patients can be contacted through voice, text, or video. The AI system also assists in launching marketing campaigns for attracting new patients. The system can track and optimize patient appointments, proactively schedule incomplete treatments, and initiate marketing campaigns based on algorithms that maximize profit. The system employs machine learning programs to interface with dental practice software and handle simple patient queries. Complex queries are redirected to the practitioner for further handling. The system can analyse data and identify periods of decreased productivity to determine the most effective marketing campaign.

Advanced learning techniques are utilized to search patient records for the most profitable treatment options. This saves time for assistants who can take prompt action before the actual appointment in case of a patient emergency. AI also supports dental healthcare professionals by providing relevant medical history or information about 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 situations where a physician is unavailable, AI can provide assistance by storing diverse patient health information. In addition to documentation and scientific coding, AI can maintain 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 extensive data, can significantly enhance predictions. The AI scientific data library can learn from the scientific database and stay updated with the latest knowledge in the field.

Artificial intelligence (AI) software in dental clinics has the capability to generate a thorough virtual database for every patient that is easily accessible. Voice recognition and interactive interfaces enable the software to aid dentists in performing various tasks. The AI system has the ability to retrieve all necessary information from the database and present it to the dentist more efficiently than a human, thereby enhancing the reliability of dental procedures. Additionally, the AI system can be trained to carry out other functions, such as integrating with imaging systems like MRI and CBCT to identify slight abnormalities that may have gone unnoticed by human observation.

However, AI in the dental field is still in its early stages and cannot replace the skills and expertise of humans. AI can complement dental operations and increase awareness of oral and maxillofacial diseases, while also encouraging patients to seek early treatment. While AI has the potential to revolutionize dental procedures in the future, there are still concerns about how and to what extent it can be integrated into practice. AI cannot serve as a complete substitute for a dentist, as clinical trials involve more than just diagnoses; they also involve analysing clinical findings and providing personalized patient care. While AI can be a useful and efficient solution in many ways, as mentioned earlier, the final decisions must be made exclusively by dentists, as dentistry is a multidisciplinary field that takes into account numerous specific factors related to human health.

Artificial Intelligence and the Monetary Facet of Dentistry.

The economic aspect of dental care is another field of dentistry where AI technology proves to be highly beneficial. With the help 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 complies with the insurer's policies. For example, if there is a need to capture an image of a fractured cusp when it is not visible in an X-ray, 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: variability among clinicians and sampling of claims for review. As for variability among clinicians, it is expected that the more clinicians review the same claim or X-ray, the more diverse viewpoints we get. Different 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 suggest that the use of AI to enhance claims assessment can substantially decrease expenses. This is because each time a claim is resubmitted or an appeal is made, it incurs additional costs for both parties. Moreover, a scarcity of dental consultants can lead to inconsistencies in claims adjudication, resulting in only a limited number of claims being processed. In such instances, even if two separate benefit claims for the same diagnosis are submitted, only one will be paid. This is because while both cases may have warranted a denial of benefit payment, the approved claim was not clinically reviewed and therefore received default approval. To avoid these situations and prevent dissatisfaction among providers and patients, AI support can be utilized to assess all reviewable claims and identify those that fail to meet the required standards for approval. With AI assistance, the claims assessment process can be carried out consistently and efficiently.

The incorporation of AI in claims assessment offers specific benefits for patients. The system's transparency will be enhanced, resulting in fewer patient appeals and unexpected denials. With regular use, the AI system will ensure the accuracy and confidence of patients in their dental benefits and treatment plans. Consequently, the assessment of claims will become more efficient, leading to quicker reimbursement and reduced administrative costs for payers. This, in turn, will lead to slower growth of premiums for patients and employers.

Another financial advantage of the AI system in dental clinics is the ability to provide instant pre-approval. Nowadays, many dental payers offer pre-approvals or cost estimates for expensive procedures. Payers prefer pre-approval to identify any contractual limitations or exclusions that may apply to a proposed treatment plan. Although some plan details can be found on payer websites, an additional clinical assessment is required, which prolongs turnaround times for payers to 2 or 3 weeks. Dental AI is expected to revolutionize this process in the near future. AI implementation has already begun for internal claims assessment and in provider offices. As the primary objective for providers and payers is to ensure the best experience for patients, and AI has the potential to bring more clarity and reliability for patients, all parties involved in the process will rely on AI solutions. Ultimately, the adoption of AI reduces financial uncertainty for patients and helps the field of general dentistry find solutions to overcome delays that can discourage medically necessary treatments.

Application of AI in COVID 19 pandemic

In the current era, the application of the AI system in the emerging corona-virus (COVID-19) situation has highlighted its potential for effective control of public health during unexpected disease outbreaks. In circumstances where there is an urgent danger presented by sudden disease outbreaks, the AI principle can ensure a prompt and secure decision-making process, thanks to its ability to analyse the extensive data.

The prevention and control of infection (PCI) program views hand hygiene as a vital component. The use of technology in hand hygiene has the potential to enhance and alter PCI procedures by introducing innovative guidance methods and evaluations. The VeryWash system is a widely used interactive booth that incorporates augmented reality-powered monitoring to instruct and measure hygiene techniques, resulting in improved hygiene performance.

The booth's portability allows healthcare personnel to use it as needed, 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 VeryWash system, a hand hygiene auditing tool, and an activity monitoring system demonstrated the feasibility of using artificial intelligence without disrupting clinical workflow.