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LEVERAGING ARTIFICIAL INTELLIGENCE IN DENTISTRY

Dentistry

Dr. S. Siva Shankar* Postgraduate Student, Department of Prosthodontics, Rajarajeshwari dental college & hospital Bengaluru. *Corresponding Author

Dr. Krishna Kumar Vaidya Professor, Department of Prosthodontics, Rajarajeshwari dental college & hospital, Bengaluru.

Dr. Shwetha Kumari Poovani Professor & head of the department, Department of Prosthodontics, Rajarajeshwari dental college & hospital, Bengaluru.

ABSTRACT

The exceptional success of Artificial intelligence(AI) in varied fields in our way of life has impressed and is stimulating the event of AI systems within the field of medication and, also, a lot of specifically, dentistry. Human brain could be a extremely advanced structure with various interlinked neurons that transmit signals throughout the body. The search of an ideal model mimicking the human brain has lead to a complicated breakthrough to what's called AI . AI could be a branch of engineering involved with building sensible computer code or machines capable of performing arts tasks that generally need human intelligence AI technologies can possible be used for assembling, processing, and organize patient-related datasets to produce patient-centered, personalised dental treatment.Hence, there's a necessity for the dentists to bear in mind regarding its potential implications for a profitable clinical follow within the future. This review describes some current and future applications of AI in dentistry

KEYWORDS

Advanced diagnostic methods,machine intelligence,neural networks tooth replacement

INTRODUCTION:

To work smarter not harder is the deepest assimilation of every human being .The deed to this constant search has given rise to artificial intelligence (AI). AI is a commonly used term as a result of adopting an overly generalized representation.[1,2] In general ,algorithms that simulate the processes of human intelligence to resolve problems are summarized under the term AI.[3] The proper concept of this term cannot be achieved simply by applying a mathematical, engineering or logical approach but requires an approach that is coupled to a deep scientific knowledge.[2] .Intelligence is defined as: "the ability of a system to act appropriately in an uncertain environment, where appropriate action is that which increases the probability of success".[3] The term "artificial intelligence" was coined on August 31 1955, when John McCarthy, Marvin L. Minsky, Nathaniel Rochester, and Claude E. Shannon submitted "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence."[4] AI is considered to be the fourth industrial revolution which employs computer technology to imitate critical thinking, decision making, and intelligence that is similar to that of humans[5]

Virtual and physical (robotics) AI are both applicable in the field of health care. The algorithms which makes the possibility of diagnosing the diseases, appointment scheduling, drug interactions,electronic health records, and imaging are the main arena of the virtual type. The physical aspect includes rehabilitation, telepresence, robotic support in surgery, and companionable robots for elderly care[5]

The last two decades have seen a surge in the interest in dental AI but it has not become a routine yet. This review aims to put forth the literature on the applications of Artificial Intelligence in all dental sectors, especially in various fields of prosthodontics and for improvising clinical decisions and forecasting successful therapy, as well as to find any present limitations in the usage of AI.(fig 1)

symbolic representation and formal logic expressed as expert systems and advanced primarily with Lisp, a family of computer programming languages	conceptualization and mathematical frameworks for mirroring neurons in the brain, formalized as "perceptrons"

Fig 1: Two major competing schools of thought developed in approaching Ai[4]

REVIEW

HISTORY

The prospects of AI in the medical field are infinite, but the realization of this rosy outlook has not yet occurred.This is because the field of AI itself has a relatively short history compared to other disciplines. The concept of AI was attempted in the first half of the 1960s.[2] In 1943, Warren McCulloch and Walter Pitts published a paper suggesting neural networks as a way to imitate human brains. In 1951, Minsky and Dean Edmunds developed the stochastic neural analog reinforcement calculator, which is recognized as the first neural network in history[2]

A "backward chaining" AI system called MYCIN, developed in the early 1970s with a knowledge base of 600 rules could provide a list of potential bacterial pathogens and recommend antibiotic treatment appropriately adjusted for a patient's body weight[6] . In 1986, DXplain, a decision support system, was released by the University of Massachusetts. This program uses inputted symptoms to generate a differential diagnosis.[6]

Efforts to develop robots controlled by AI have been continuously carried out to maximize human convenience and safety.[2] various types of diagnostic robots have already appeared in the medical field. Nowadays, the development of semi-automatic surgical operation AI robots, which assist physicians in various aspects, has become more apparent[2]

SUBCONCEPTS OF A.I

There are two themes of thought that divide the entire range of meanings currently encompassed by the term Artificial intelligence.[2] Machines are said to exhibit different competencies ,either weak or strong.(Fig.2)

Strong AI is a theoretical form of machine intelligence which supports the view that machines can really develop human consciousness equal to human beings.It invlovles complete digitalization in the form of algorithms through computing to replace the intellect of the person.[2] Strong A.I mimics human Intelligence entirely which uses non natural artificial hardware and software constructions[3]

If a human mind can be synthesized in a formal, logical manner, then, in principle, a computer has the potential to completely replace a person's mind which implies that the computing machine can self-consciously work without the help of a human reaching the stage of recognizing and "understanding" the object in an autonomous and active way,[2] which is still a fiction at present. Computers attaining strong AI will be the biggest innovation in this field which will have a huge impact on human civilization[1]

We experience weak AI or simulated thinking in our day to day life, starting with the basic computational language which we use to command the computer programme till the robotics[1]. It attempts in the reproduction of the human intelligence, which is expected and intended by strong intelligence.

Weak AI attempts to implement a system that develops the problem-solving ability through learning using some of the sense and thinking mechanisms of people. bio-inspired artificial neural network is a widely used method that applies weak AI and in the process of machine learning.

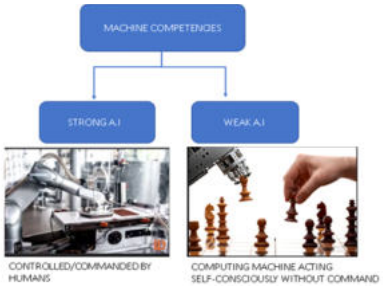


Fig 2 : subconcepts of A.I

PRINCIPLE OF ARTIFICIAL INTELLIGENCE

Before the A I system comes into action it undergoes training followed by the testing phase. AI operates in two phases: "training" in the first phase and "testing" in the second. The parameters of the model set are determined by the training data. Retrospectively, the model makes use of data from prior examples, such as patient data or data from data sets containing various examples. These parameters are then applied to the test sets[5]

The artificial intelligence system is mainly based on the process of machine learning and nueral networking Inspiration for the formation of artificial networks can be found in the biology of the human brain. "An artificial neuron is a mathematical function conceived as a coarse model of a biological neuron.

The action is similar to that of a neuron system which aims in transfer of information from one axon to another: in the artificial neuron the input is fed in to the weighted nodes (representing the synapses), which gets activated in the hidden nodes (representing the axon), and pass this activation to a nonlinear function called transfer function, in order to generate the output signal. Each neuron acts as an elementary processing unit[3](Fig.3)

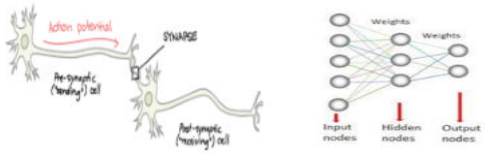


Fig 3: TRANSFER OF INFORMATION IN A NUERON TRANSFER OF INFORMATION IN A.I

KEY ASPECTS OF ARTIFICIAL INTELLIGENCE(fig 4)

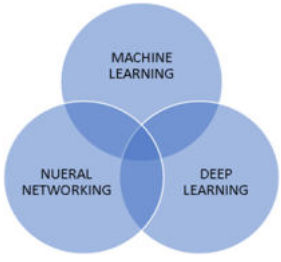


Fig 4 : key aspects of A.I

NUERAL NETOWRKING

It uses artificial neurons to set the algorithm. It works almost similar to the human brain. Nueral network are set of algorithms that compute/transfer signals in artificial nueron.nodes are connected in hierarchial layers. A neural network is composed of an input layer, an output layer and hidden layers in between. It is possible to have one or a few hidden layers (shallow neural network) or multiple hidden layers (deep neural network, DNN)

ANN is the most popular AI technique in dental. ANNs are computational analytical tools which are inspired by the biological nervous system. They consist of networks of highly interconnected computer processors called 'neurons' that are capable of performing parallel computations for data processing and knowledge representation[7]

Kim et al used artificial neural networks to build an AI that can predicate dental caries and toothache based on frequency of tooth brushing, the time taken, using of dental floss, the frequency of tooth brush replacement and other broad factors such as diet and dental visits.[8] Bayesian network analysis is used to identify relationships between various factors affecting the diagnosis and final treatment outcome of impacted maxillary canines[9]

Data mining research of a large number of patient's restorative data found that variances in tooth restoration material are major determinants in influencing the lifespan[10]

Several variations of artificial neural networks gained attention like convolutional neural networks (CNNs) for image classification challenges and dilated convolutional neural networks (DCNNs) for sematic scene segmentation challenges such as segmentation of structures in an oral radiograph.[11]

In research, CNNs are being used for dental imaging diagnosis. convolution nueral network has a convolution operation which acts as matrix multiplication between the filter and data.it has several hidden layer,where first layer learns the basic feature and will pass the information to the remaining layers to detect more complex features

Using a convolutional neural network (CNN), Eun and his colleagues observed directed tooth localisation for periapical dental X-ray images [12]. Imangaliyev and his co-workers in 2016 worked on CNN model for classification of dental plaque images using 427 datasets [13]. In 2017, Aubreville et al. for diagnosing oral squamous cell carcinoma (OSCC) in oral cavity used nueral networking approach [14]. In 2017, De Tobel and his colleagues for estimating age using panoramic radiographs to stage lower third molar growth identified an automated technique [15]. Lee et al. worked on CNN model for diagnosis and prediction of periodontally compromised teeth

MACHINE LEARNING

Machine learning is the subfield of artificial intelligence in which algorithms are trained to perform tasks by learning patterns from data rather than by explicit programming[12] (fig 5)

Machine learning can be grouped into three main approaches: Each approach can address different needs within health care[4]

(1) supervised,
(2) unsupervised,
(3) reinforcement learning.

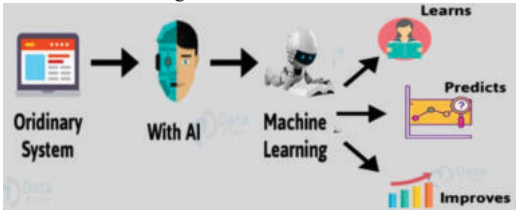


Fig 5: When an ordinary system is incorporated with A.I the machine learning occurs in three phases: training phase where the machine learns from a large database, validation phase where the machine predicts the result, inference/application phase where the machine improvise and is applied in real case

SUPERVISED[4]

Supervised learning focuses on learning from a collection of labeled examples. Each example (i.e., patient) is represented by input data (e.g., demographics, vital signs, laboratory results) and a label (such as being diabetic or not)

UNSUPERVISED[4]
Unsupervised learning seeks to examine a collection of unlabeled examples and group them by some notion of shared commonality. Clustering is one of the common unsupervised learning tasks. Clustering algorithms are largely used for exploratory purposes and can help identify structure and substructure in the data

REINFORCEMENT LEARNING[4]
Reinforcement learning differs from supervised and unsupervised learning, because the algorithm learns through interacting with its environments rather than through observational data alone

DEEP LEARNING
The ML is a subset of AI, meanwhile, DL, in turn, is a subset of ML. That is DL is an aspect of AI; the term deep learning refers to artificial neural networks (ANN) with complex multilayers. This algorithm uses multiple layers to detect simple features like line, edge and texture to complex shapes, lesions, or whole organs in a hierarchical structure.[11]

Conventional neural networking is an example of deep learning.

CLINICAL DECISION SUPPORT SYSTEM
AI has revolutionized in the field of dentistry and making the dentist's task easier. The clinical decision support systems that work on the AI technology are mainly designed to provide expert support to the health professionals[16]

Clinical decision support systems is defined as, any computer program that has been designed to help health professionals in making clinical decisions, and also deals with the medical data or with the knowledge of medicine necessary for interpreting such data. [16]

In some cases, dentists do not have enough knowledge to make the right clinical decision in a limited period. AI applications can serve as their guide so that they can make better decisions and perform better[16]

The CDSS consist of a network between a dynamic knowledge base and an inferencing mechanism that are usually a set of rules derived from evidence-based by experts[9] (fig 6)

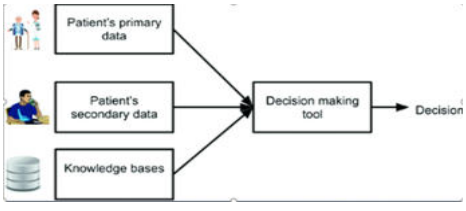


Fig 6 : CDSS:A TOOL FOR DECISION MAKING

USES
CDSS uses a large amount of clinical data and can predict susceptibility to dental diseases, helping in accurate diagnosis and treatment planning.[17] Booking and coordinating regular appointments according to the convenience of the patients and dentists.[17]

Standardized Dental Charting Documentation including patient history is of paramount importance in dentistry.[18] CDSS plays an immense role in documentation of the records making the work easier.

Speech recognition systems would be helpful in the hands-free documentation process. These systems allow the clinician to dictate clinical findings into a computer system that digitizes the voice input and creates a document or clinical record.

A non-invasive method for detection of precancerous and cancerous oral lesions uses computer-assisted analysis of the oral brush biopsy and is termed OralCDx. It can aid in confirming the nature of apparently benign oral lesions and revealing apparently benign lesions that are in actuality either precancerous or cancerous. OralCDx appears to determine the significance of an oral lesion definitively and detects innocuous-appearing oral cancers at an early and curable stage[19]

There are mobile applications available which help the patients to identify malignant melanomas by comparing the pictures from the patient with a vast interphase of pictures of lesions from around the world. (eg. Mole Check App, OnlineDermClinic, SkinXM)[20]

Drug prescribing. In dentistry one of the major examples of integrated CDSS. Electronic records systems linked to order entry systems with CDSS can supply patient data needed for proper drug dosing.[18]

ELEMENTS OF CDSS[21]
Most CDSSs have four basic components: inference engine (IE), knowledge base (KB), explanation module, and working memory (Figure 7) [21]

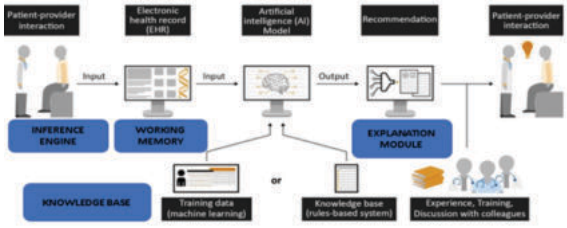


Fig 7 ELEMENTS OF CDSS

INFERENCE ENGINE
IE is the main part of any such system. The IE uses the knowledge on the system and the knowledge about the patient to draw conclusions regarding certain conditions

KNOWLEDGE BASE
The knowledge used by the IE is represented in the KB. In a system for management of caries, the KB will contain knowledge on risk factors for new lesions and risk scores. Knowledge bases may be built with the help of a domain expert or by an automated process.

In the case of a admin expert a knowledge engineer (expert on building KBs) with the help of a clinical domain expert creates, edits, and maintains the KB. In an automated process, knowledge is acquired from external resources such as databases, books, and journal articles by a computer application.

WORKING MEMORY
The collection of patient data may be stored in a database or may exist in the form of a message. This collection is known as "working memory." Patient data may include demographics (i.e., date of birth, gender), allergies, medications in use, previous dental or medical problems, and other information

EXPLANATION MODULE
The last component, the explanation module, is not present in all CDSSs. This module is responsible for composing justifications for the conclusions drawn by the IE in applying the knowledge in the KB against patient data in the working memory

APPLICATION OF ARTIFICIAL INTELLIGENCE IN DENTISTRY
Since its inception in the 1980s, the field of artificial intelligence tutoring has reached a long path. Both the systems, augmented reality and virtual reality are being used widely in the field of dental education to create situations that simulate clinical work on patients and eliminate all the risks associated while working on a live patient[22] the use of AI technology in prosthodontics is rare. Prosthodontics itself is a diverse and complex area of dental medicine and one that may benefit from the routine application of AI technologies.[3]

RADIOLOGIC AND DIAGNOSTIC APPLICATIONS:
A.I system can be integrated with imaging systems like MRI and CBCT to identify minute deviations from normalcy that could have gone unnoticed to the human eye[22]. This can also be used to accurately locate landmarks on radiographs. In the field of orthodontics, AI can help predict orthodontic movement based on patient ethnicity and anthropological background[23]

ANN is found to act as a second opinion to locate the minor apical foramen, thereby enhancing the accuracy of working length determination by radiographs and in diagnosing proximal dental caries[11]

CNNs have demonstrated a precision rate of 95.8–99.45% in detecting and identifying teeth, almost rivaling the work of clinical experts,

whose precision rate was 99.98%24,[25]

In 3000 periapical radiographs of posterior teeth, a deep CNN algorithm was able to detect carious lesions with an accuracy of 75.5–93.3% and a sensitivity of 74.5–97.1%. This is a considerable improvement over diagnosis by clinicians using radiographs alone, with sensitivity varying from 19% to 94% Lee et al. evaluated the efficiency and performance of AI in diagnosis and detection of osteoporosis. In this study deep convolutional neural network (DCNN) based computer-assisted diagnosis (CAD) systems was applied for detection of osteoporosis, using panoramic radiographs and exhibited very promising results[26]

Hiraiwa et al., reported of applying CNNs for detection of sjogren's syndrome (SjS) on CT images and compared the results with the performance of radiologists and showed a higher diagnostic performance[27]. In another study by Murata et al., the authors applied the deep learning system for diagnosing maxillary sinusitis on panoramic radiography[28]

Dental radiographs can be interpreted by the software(Second Opinion,Pearl;Denti.AI;VideaDetect)with machine learning algorithms. These softwares utilize computer vision to assist clinician by automatically generating treatment proposals based on deep learning algorithms. However the treatment plans are still limited to simple procedures such as fillings,partial coverage and full coverage restorations.[29]

In 3D radiographs such as tomography scan the annotation of anatomical landmarks and segmentation of bone and teeth structures are achieved by A.I.one company(Orca-Dental AI) introduced their software with annotation ability,automatically segmenting anatomic structure such as maxilla,mandible and teeth.Nerve recognition and pathologic identification are possible with these algorithms.[29]

ARTIFICIAL INTELLIGENCE IN REMOVABLE PROSTHODONTICS

Digital techniques such as CAD CAM (Computer Aided Design and Computer Aided Manufacturing) have been advocated in the fabrication of removble dental prosthesis and complete denture prosthesis[23]

AI's considerable bonus is the ability to assess and learn from the millions of doctor-approved designsin the database, with cases added to the cloud on a regular basis. Esthetics are often evaluated by measuring the potentially enormous number of dental anatomy information available[1]

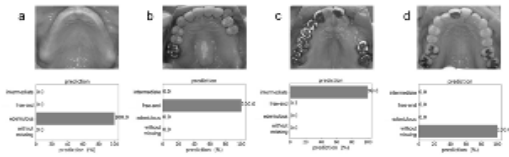
In order to provide ideal esthetic prosthesis for the patient various factors like anthropological calculations, facial measurements, ethnicity and patient preferences has been integrated by a design assistant, RaPid for use in prosthodontics. RaPiD integrates computer aided design, knowledge based systems and databases, employing a logic based representation as a unifying medium. With the help of Artificial Intelligence, the computer can actually guide the dentist during the entire procedure of making a digital impression and aid in making an ideal impression[11]

CAD CAM dentures have been proposed through pre polymerized PMMA blocks and 5 axis milling with computer software. The advantages of CAD CAM dentures are lesser clinical visits, milling pre-polymerized dentures eliminating occurrence of porosities with better denture fit.[30,31]

Takahashi et al.,demonstrated a way for classifiying and desigining of the dental arch using CNN using image net software.[32]

The system is provided with a large dataset and made to learn. The computer reads the training dataset which is already classified as true arch type and creates the classification rule by learning them.the testing dataset is used to test the predicted rule and the accuracy of learning is improved by learning again and again.after finisihing the learning the computer classifies new images of dental arch with prediction rate based on the rule. clincians finally have to judge whether the prediction is correct or not.[32](fig 8)

Fig 8 : dental arch classification using A.I [32]



FIXED DENTAL PROSTHESIS AND ARTIFICIAL INTELLIGENCE

For a restoration to be successful the margins and finish line of a tooth preparation should be accurate. If the margin is visible and the intra oral scan is accurate,the software can then automatically mark the preparation margins and the finish line on tooth preparation with high accuracy and precision. After adter margin marking the preparation scans can move forward to digital design and milling. An AI based software (Glidewell.io in-office solution,Glidewell) is available to automate the design of single posterior crown in the laboratory.[29](Fig 9)

Artificial intelligence models are valid tools to improve tooth shade selection, automated restoration design, map the preparation finishing line, optimize the manufacturing casting procedures.[33]

Business entities such as dental service organization managers can use this technology to score their dental practioners to make decision on who needs further training and who is excelling clinically.

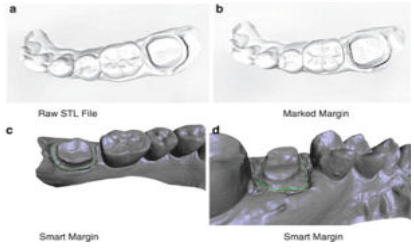


Fig 9 Margin marking by A.I system[34]

IMPLANT SYSTEM IDENTIFICATION USING A.I

Artificial intelligence algorithms can provide a powerful diagnostic tool to identify dental implants by using radiographical images, predict implant survival, or assist and optimize dental implant designs[35]

Compatibility is different depending on the dental implant system. Some systems are not compatible with other brands, whereas others are broadly compatible. As mentioned, these factors directly affect the maintenance of implant prosthesis.

Several studies have applied deep learning and convolutional neural networks for identifying dental implant systems and achieved an accuracy of 0.80–0.95 in identifying the implant systems[36,37]

In a study by sukegawa etal., deep CNNs surveyed were able to classify 11 dental implant systems extracted from digital panoramic X-ray images with high accuracy, despite mixed conditions at the implant-treatment stage. In particular, VGG16 and VGG19 finely tuned CNNs showed excellent classification performance. Grad-CAM for each network was also shown to understand the characteristics of each convolutional layer for each implant fixture. These results will play an important role in determining dental implant brands from panoramic radiographs using deep learning[38]

Fig 10 shows an example of implant identification

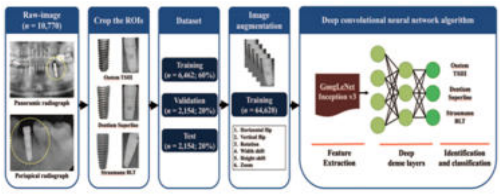


Fig 10

From the raw image of OPG or periapical radiograph,the area of interest in cropped and the dataset is obtained for training,validation

and test. Using the googlenet inception v3 software,the information is passed on to different hidden dense .

Optimal implant positioning plays a vital role in the overall success of the prosthesis with consideration to the mesiodistal, apicocoronal and buccolingual positioning and placement. One of the latest innovations is dynamic navigation, which may allow surgeons to place implants with accuracy similar to stereolithographic guides based on 3D, prosthetically directed plans. It allows a real time tracking and implant placement .The virtual drill appears on the screen as the operator begins the drilling and the progression of the drill is visible in 3D[39,40]

MAXILOFACIALAND A.I

The bionic eye, developed in the United States, has already been tested in a dozen patients with vision damages. Without the need for surgery, these devices can benefit the people in attaining vision with the help of artificial intelligence. In this way, a smart camera mounted on special glasses allows the user to read text or recognize faces. With the help of a small headset, the expertise processes the information seized by the camera and converts it into audio, which is conducted to the ears of the visually impaired person. [1]

Due to amputation of limbs, patients can lose the sensory capacity in those areas. Artificial skin developed by researchers from the California institute of technology (USA) and the federal polytechnic school of Zurich (Switzerland) is changing this scenario. The tissue composed with a thin, clear film of pectin and water, senses temperature variations in the range between 5 and 50 degrees Celsius.[1] (fig 11)

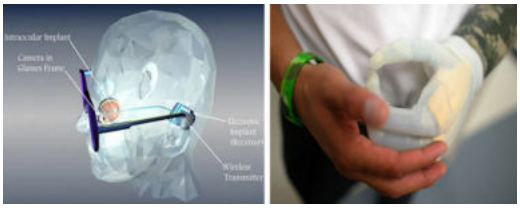


Fig 11 : application of A.I in maxillofacial prosthesis

SMILE DESIGN AND A.I

Smile design has been a useful tool for team communication and patient motivation.currently there are around 15 smile designing software available for clinician.all of these software rely on the input and the preferences of the clinician to design the shape and alignment of the future smile.A new interactive cloud-based platform(smile cloud,ADN3D Biotech)incorporating digital smile design,the treatment plan and the communication tool among clinician,technician and patient was introduced. [29]

Once the required patient data (photos,videos) are uploaded the A.I engine searches and proposes natrual shape of teeth and alignment .
The proposed smile design can be modified by clinician and then used to create STL file for creating mockup model/ preparation guide or surgical guide.

In order to provide ideal esthetic prosthesis for the patient various factors like anthropological calculations, facial measurements, ethnicity and patient preferences has been integrated by a design assistant, RaPid for use in prosthodontics(fig 12) a novel concept: the REBEL system, which is designed as a digital lab, that converts the 2D design into 3D and creates a digital wax-up immediately. With the help of AI, the 2D is created by the VisagiSMile concept that relates the facial perception and the personality of the patient to the smile design by applying algorithms for computing the optimal combination of the incisal silhouette, tooth axis, dominance of the centrals and the combination of individual tooth shapes out of thousands of possibilities.

Fig 12 : Application of A.I in smile designing

CONCLUSION

Although A.I can improve the accuracy and precision of the treatment,it is far from being able to replace dental professional.Also they lack subjective sense of human empathy and moral judgement A.I in dentistry requires more quality clinical research to maximise the use of these innovations.

There is a common notion that artificial intelligence will replace the clinicians, which is why they have been quite skeptical in embracing it. As a matter of fact, the incorporation of these techniques will not only increase the efficiency of the specialists but also help in better patient care. It needs to be understood that artificial intelligence has been given birth by humans, therefore, it will never be able to enslave them in unfamiliar situations unless trained to do so.

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