Cloud Driven Big Data Synergy in Dentistry

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Abstract. Cloud driven big data synergy has changed the dental healthcare system. With the integration of AI, it has ushered in dentistry 4.0 where artificial intelligence and machine learning will identify patterns to help in diagnosis and management of oral diseases. The increasing requirements for appointments have pushed dental healthcare providers to digitalize their practice generating volumes of data every day. The storage of large sets of data in cloud has enabled a smooth flow in patient care, access to patient files and tele dentistry.

Keywords: Dentistry 4.0, digital dentistry, big data, electronic health records, cloud, predictive pattern

1 Introduction

The global market for cloud based dental practice software has grown considerably with an expected high growth expansion due to increase number of dental clinics being set up. The awareness among the current generation about the importance of oral health, a growing elderly population and an increase in demand for cosmetic dentistry has resulted in increase footfalls, necessity for dental office management software's and abundant clinical data which is being used for research [1]. Digital transformation has changed the scenario of the dental healthcare system. It has changed how dentists engage with clients, dental staff, consultants and vendors. It has simplified and streamlined the process, improved patient experience and changed business model. Digitalization has increase work efficiency and precision with intraoral scanners, digital radiographs, CBCT, dental software's to manage data and CAD CAM for prosthetic design [2]. Increase use of artificial intelligence in operative, diagnostics, practice management of dental office, billing insurance and patient care has moved the dental environment steadily towards dentistry 4.0. Central to this is the availability of an enormous amount of clinical data that is being generated every day. The data must be identified and stored in a proper data base. Artificial intelligence depends heavily on the availability of clinical data like patient health records, radiographs, intraoral scans and treatment outcomes. AI algorithms analyze the large amount of data generated every day and recognize patterns that might skip the naked eye. AI integration in radiomics has enabled radiographic

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interpretation and diagnosis of oral pathological lesions. The large amount of data will further train and validate AI findings [3]. An intelligent digital mesh integrates people, devices, internet of things, processes, services and data in a corroborative environment. It has changed from a simple network /web to multiple webs, user driven applications, cloud storage, ubiquitous data sets and information access [4]. Dentistry 4.0 is the application of AI driven decision making for personalized and predictive dental care. It is data driven, the real time data collected from various devices supported by the cloud [5].

2 Growth of big data in dentistry

Electronic health records are the cornerstone of big data in dentistry. Dental records are crucial information's describing the patient's oral health comprehensively. They serve as antemortem records in victim identification in forensic dentistry. Previously stored as paper files, they are now digitalized and accessed anywhere and at any time by the dentist or the client through his portal. EDR can be linked with the patient's oral health records at a different dental office for continuity and the patients medical record for holistic purpose. An integrated approach helps in public health surveillance in developing predictive models for widespread dental diseases like dental caries, periodontitis and oral cancer. Dental informatics include the collaboration of the IT sector and dentistry with dental software's like ADSTRA and Dentrix paving the way. The files are charted as a single unit for a dental client and this prevents duplicates/multiples being created. Table 1 show the types of data generated in dental office.The file can be updated in subsequent visits and thus hold information of the dental client as a single paperless document [6]. Digital radiographs, radiovisiography, OPG, CBCT and intraoral scans are standard diagnostic procedures that are used in the dental office everyday creating a large amount of data every day. Fig.1 shows the 5Vs of big data [7].

Table 1. Types of data generated in dental office

Data generated in dental office
Patient information
Medical history
Dental history
Allergy and medications
Clinical data
Treatment record
Radiographs
Laboratory records
Dental laboratory records
Billing and insurance

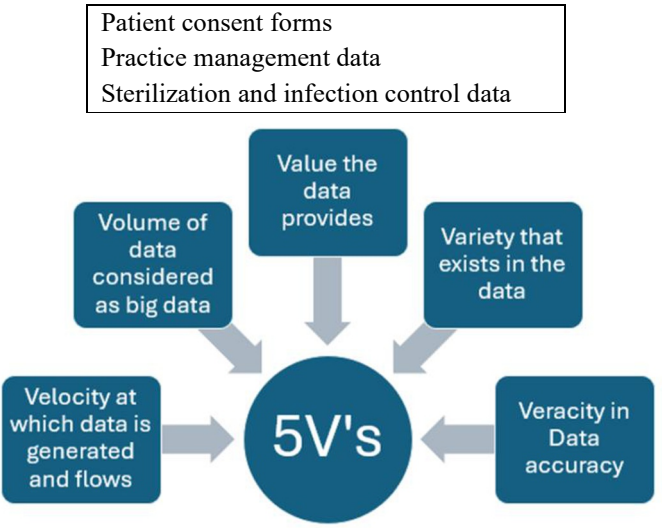

Fig. 1. 5Vs of big data(7)

3 Need for cloud storage

Cloud computing provides centralized storage of data and provides online access to services and resources through internet. The Data is not stored in the dental office but in remote servers that are interconnected. This reduces the burden of the dental office in storage and retravel of the patient files both in storage and manpower. A patient might visit several dental clinics and use different health insurances [8]. An integration and exchange of information within administrative boundaries takes place between these sectors. Cloud data sharing is easily available and can be accessed by the dentist, consultant and dental client from their portal. The dental client can access the information but cannot make changes. The advantages of cloud computing is scaling up, Lowering IT cost, ease to access patients previous health records, know immunization and health details like drug allergies and medications, paperless, compact, reduction in errors ease of operability and search. Fig. 2 shows the Advantages of cloud computing in dentistry.

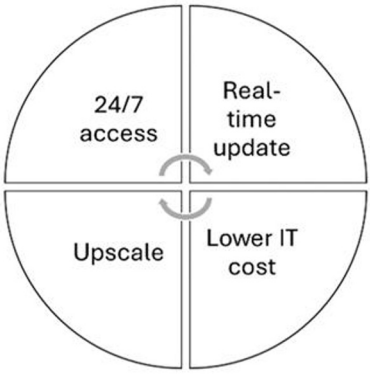

Fig. 2. Advantages of cloud computing in dentistry

In SaaS model, the same software model is used by multiple dentists in multiple locations. The user has a unique ID and the data generated will be stored separately in accordance to the ID [9]. SaaS vendor manages both the hardware and software tool. The end-user in the dental office will access through registration, and store clinical data in the cloud instead of the dental office. SaaS is one of the three Cloud based computing along Platform as Service PaaS and Infrastructure as Service IaS. MocDoc, tab32, Practo Ray and Dentalsoft are some of the cloud based dental software's [10].

4 Applications in Dentistry

AI integrated with big data and cloud computing synergy has transformed dental environment. Digital imaging with integrated AI interprets radiographs and scans and aid in diagnosing and treatment planning. The use of virtual imaging helps understand the human anatomy and helps describe dental procedures to patients to reduce apprehension. Dental aligners are fabricated considering the predictable movement of the tooth augmenting their use and acceptance despite high cost by patients. Oral sensors monitoring hygiene, track periodontal changes give real time data. CAD CAM and 3D printing help design precision prosthesis, surgical guides, aligners reducing chair time in an integrated workflow. AI integration in research has helped in identifying biomarkers and personalized medicine.

Tele dentistry provides access and delivery of oral healthcare in remote areas by providing clinical information and images. A real time conference between the patient primary dental health care provider and consultant takes place without the patient not actually visiting the dental office. The clinical information and static images are documented in the dental office. Remote monitoring and online consultations have saved cost and time.

Insurance scams all over the world result in a huge loss of expenditure in public health care. The three players – the insured, the healthcare provider and the insurance provider may have varied interests resulting in fraud like over-diagnosis, fake medical treatment and improper claims settlement. Fraud, waste and Abuse is used in the healthcare system to denote the unnecessary expenditure, excessive costs and fraudulent activities. AI integrated big data and cloud synergy use data mining to compare the current claims against previous generated data points for accurate processing and preventing insurance frauds.

Predictive models using AI and ML for oral diseases and oral potentially malignant disorders help in identifying the diseases in early stages reducing mortality and morbidity significantly. Learning algorithms have demonstrated the ability to identify oral disease at early stage with high accuracy of 82.1 to 95.2% in a study by phan et al. The advancements can be utilized in public health care systems in assessing and monitoring caries risk in school children and morbidity associated with periodontal diseases among adults. The integration of big data and AI in forensic odontology help in comparing post mortem records with antemortem records. This is a tedious process and AI integration helps in recognizing patterns which can help in victim identification. In case of mass disasters, volumes of data are generated and compared across borders.

5 Compliance in dental cloud informatics

Dental clinics/ hospitals generate a lot of primary data. These are properly standardized documentations that contain patient information, medical history, dental history, dental procedures underwent in the clinical setup and include billing and insurance. Hence, care must be taken to safeguard the data as most dental clinics now have software's to handle the everyday complex processes of the dental offices. Privacy must be guarded and security measures in place. The dental office must take all measures in compliance of the law. HIPAA (Health insurance portability and accountability act) by the United States government and GDPR (General Data protection regulation) in the European union and Information Technology Act, 2000 are safety regulations that protect an individual's privacy and data rights while enabling AI to its maximum potential. In India, the Indian medical association mandates the health practioner to maintain health records for 3 years. Indian dental Association recommends the storage of record for minimum of 5 years considering the judiciary needs. Preservation of the records is the dentist's responsibility.

6 Result and Discussion

A clinically annotated dataset on patient demographic data, clinical risk factors, and patient imaging-derived features was used to test the proposed medical decision-support framework. The standard medical evaluation metrics that were used to

evaluate model performance are accuracy, sensitivity, specificity, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC).

6.1 Diagnostic Performance

The diagnostic accuracy of the proposed machine learning model was high and the model was able to differentiate high-risk and low-risk patients shown in Fig.3. The overall accuracy of the model classification was 94-97% which shows a high level of discrimination between pathological and non-pathological cases. The sensitivity value of 92-96 indicates that the model is effective in detecting the true positive cases correctly and this is essential in screening medical cases to reduce false diagnoses. Specificity was 88-93 and indicated how the model has the potential to accurately classify healthy or low-risk patients and minimize the number of false alarms.

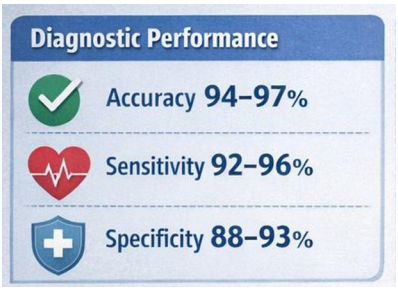

Fig. 3. Diagnostic Performance rate

6.2 Comparison to Traditional Clinical Assessment

Compared to classical forms of clinical assessment and classical statistical models (rule-based scoring and logistic regression), the suggested framework achieved better results shown in Fig.4. The conventional methods had a precision of between 78 and 85% with reduced sensitivity to detect the disease in its early stages. The enhanced functioning of the proposed system is explained by the possibility to examine non-linear association between numerous clinical and image variables that is frequently neglected during the evaluation using manual or threshold-based approaches.

Fig. 4. Comparison of traditional and proposed method

6.3 Results of Risk Stratification

The system was effective in stratifying patients by low-, moderate-, and high-risk groups, which allowed making clinical decisions shown in Fig. 5. Clinically significant findings were highly correlated with high-risk a classification, which supports the idea of the possible application of the model as a screening and triage instrument. Intermediate-risk cases were selected to undergo close follow-ups whereas low-risk cases needed minimum clinical attention, which was used to maximize the use of healthcare resources.

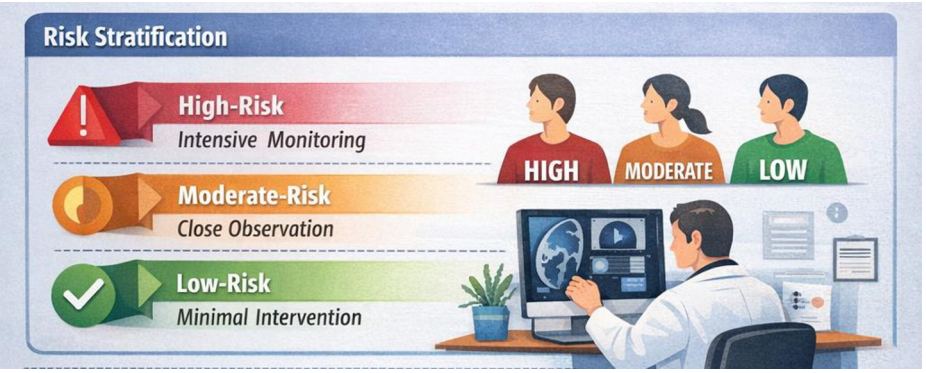

Fig. 5. Risk Stratification

6.4 Strength and Clinical Faithfulness

Cross validation experiments showed that the models are robust and stable as they perform similarly on different data partitions. The low false-positive rate minimised the unwarranted follow-up investigation and the high true-positive rate guaranteed a clinically significant detection. These findings confirm the validity of the suggested framework in practice-based medical applications.

7 Limitations and challenges

Successful integration of AI with cloud supported big data comes with a few limitations. There is an initial investment cost and vendor lock period. Infrastructural challenges must be met and an update with the fast-paced everchanging technology. Training and skill development among dental staff who lack digital proficiency and are unwilling to change is a major limitation in the dental clinic. Standardized protocols in documentation must be maintained. Security and privacy are a matter of concern regarding sensitive information in cloud-based platforms. Secure storage and cybersecurity ensuring compliance with data protection regulation is essential.

8 Conclusion

The global market for cloud based dental practice software has grown considerably. Cloud computing offers numerous advantages to dental practices, revolutionizing how they manage patient data, collaborate among team members, and ensure regulatory compliance. For dental practices, cloud computing involves utilizing internet-hosted services to manage and store data, such as patient records, x-ray images, and other sensitive data. This approach allows dental businesses to reduce their dependence on traditional software and hardware by hosting their data on servers operated by cloud service providers. The cloud services most pertinent to dental practices include Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). Among these, SaaS is the preferred choice for integrating cloud-based dental software due to its user-friendly nature and extensive support for practice management needs, encapsulating a wide range of functionalities within cloud-based software solutions

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