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Dental Science

INTERNET OF THINGS: ALEXA APPLICATION IN DENTISTRY: A FUTURISTIC REVIEW

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ABSTRACT The Internet of Things (IoT) describes the network of physical objects or 'things' that are embedded with sensors, software and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. Internet of Medical Things (IoMT) has revolutionized health care sector drastically since last decade. Recent advances in digital world have helped to achieve prevention and management of chronic diseases by the IoMT technology based devices in medical field. Advanced science, cloud technology, and new generations of smart-phones with integrated apps have helped patients to track their diseases continuously on daily basis. Dentistry has also transformed completely due to establishment of computer-based advanced technologies, new preventive disease measures, and improved diagnostic techniques in last few years. Internet of Dental Things (IoDT) is an innovative approach to achieve prevention and management of dental caries, periodontal diseases, oral cancers, and other dental diseases. IoDT could play vital role in collection and monitoring of patients' data for oral health care; moreover this data could be used in eventual risk assessment and further research. This paper reviews IoT and its possible application in dentistry; additionally it also introduces IoDT technology dependent oral heath-care model and architecture applied to dentistry. In addition, it also reviews data collection devices used with reference to IoDT technology. Thus the overview compiles recent studies on arising digital progressions in dentistry and recommends IoDT as the futuristic advent in the advanced clinical dentistry.

KEYWORDS : IoDT, Recent advances, Smart dentistry, Technology.

1. INTRODUCTION:

A healthy mouth is a unique and invaluable asset and yet an integrated component of general health and quality of life.[1][2] Dental caries is one of the most common problem affecting people of all ages, acids produced by fermentation of carbohydrates such as sucrose, glucose, fructose by the plaque bacteria such as Streptococcus mutans leads to demineralization of enamel and damages the dentin-pulp complex which leads to acute/chronic pulpitis that is associated with severe toothache. Other dental problems includes tooth malalignment, tooth fracture, gingivitis and periodontitis which is associated with alveolar bone loss.[3] The monitoring of periodontal tissues and oral mucosa can play a significant role in monitoring the patients cardiovascular and cerebrovascular diseases, diabetes, AIDS and other problems. [4][5][6] Hence, early diagnosis and treatment is necessary for prevention of tooth loss.

The field of dentistry has historically been a technology-driven healthcare domain. It has proven to be one of the forerunners when it comes to adopting new technological revolutions. A network of interconnected computing devices with the ability to share data and have communications across the server is called as internet of things. When the data being transferred is medical, health and fitness related, it is commonly known as the Internet of Medical Things. In medicine, smart devices as a part of the internet of medical things are not only revolutionizing self-health management, but it is also facilitating better healthcare management via tele-health and remote patient monitoring. IoDT can also play a vital role in collection and monitoring of patients' data for oral health care, eventual risk assessment and further research.

2. TECHNOLOGY:

A brief architecture of how the IoT system works is explained. A basic IoT system constitutes the sensors, cloud server, database and the user interface (Fig. 1). The user can access the server and end devices from all over the world with help of internet. Intraoral sensors are those devices with sensors that could be invasive or non-invasive, and those could be placed closed or next to mucous membrane in oral cavity for continuous observation of patient functions without disruption to patient.[7] Wireless sensors that are usually used for continuous monitoring are placed inside the oral cavity. Invasive sensors can be used along with dental implants in the alveolar bone region. Non-invasive sensors can be attached to buccal or lingual tooth surface or to any oral devices/appliances. Sensors should always be placed in such a position, where continuous monitoring is achieved along with no discomfort or interruption to the patient.

Two common computing technologies used in IoT are edge and cloud computing. Edge computing is used in applications to process time sensitive data, which means the data is used instantly without any waiting time, while cloud computing is used in applications to process data, which is not time sensitive where the data can wait for months. Besides edge computing is preferred over cloud computing in remote areas, where there is limited connectivity. When a patient uses a sensor assisted device for disease tracking, it communicates the examined data to the patient's mobile phone or tablets, and this ultimately forms a network called 'body area network' (BAN). IoT based devices are commonly used to monitor, transfer and incorporate patient's data to cloud/edge computing network for further analysis and diagnostics.[8]

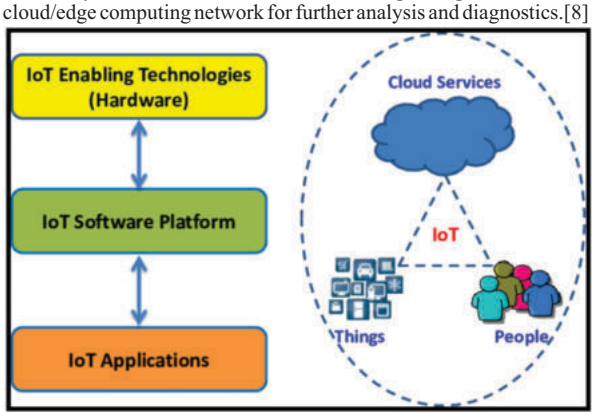

Fig 1: Basic architecture of IOT

Where can IOT devices be incorporated?

2.1. Smart Implants - A very useful application of IoT for dental care comes in the form of tooth-mounted implants (Fig. 2). These implants can be placed on the surface of the tooth or embedded inside the tooth cavity attached to dental implants (Fig. 3). The implants can be used to monitor the food intake of individuals. The data collected is then shared with the doctor in real-time. The smart implants help dentists keep track of the diet of the patient. It proves the most useful after a dental procedure and dietary restrictions are levied on the individual. People usually cheat on diets recommended by dentists after a dental procedure after a few days, which results in an increase in the recovery time or creates other complications. The smart implants, however, ensures that the patients follow the diet prescribed by the dentist strictly. It eventually leads to a better outcome of the dental procedure and results in recovery as intended.

Fig. 2 : Tooth mounted sensor

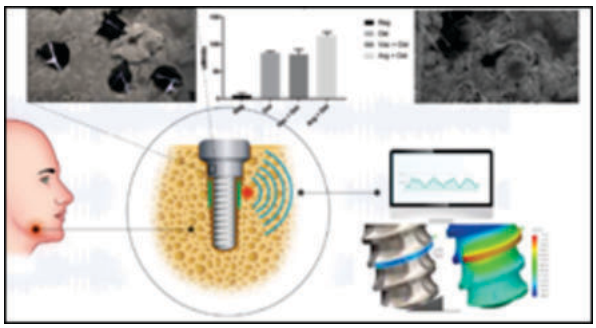

Fig. 3: Dental implant mounted sensor

2.2 Smart toothbrushes

Smart toothbrushes can be used to gather patient data regarding their brushing activities. These toothbrushes come embedded with a plethora of technologies such as cameras, pressure sensors, and much more (Fig. 4). The inbuilt camera is used to track the brushing activity. It can replicate an oral examination procedure during the routine brushing procedure. The dentist can examine the teeth of the individual from the data captured by the camera during the brushing activity. Additionally, pressure sensors attached can be utilized to determine if the brushing process is carried out properly. It can measure whether the right intensity or force is applied and can alert the user in case of any deviations. All the data can be shared with the dentist in real-time and thus increases the preventive care process. Most of the dental issues are caused due to improper brushing and thus with the help of smart toothbrushes, the problem can be easily solved.

With the help of IoT devices, the dentists can look after the dental health of their patients outside the clinic and this approach results in better preventive dental care with improved health outcomes. This is just the first wave of the use of IoT for dental care which is restricted to just a few applications. However, we can imagine a future of interconnected devices with the inclusion of other technologies like big data, IoT, and blockchain coupled with IoT to provide better dental care inside and outside the doctor's office round the clock.

Fig. 4: Smart tooth brush

3. DISCUSSION

Liu et al [9] developed a smart dental Health IoT system based on intelligent hardware, deep learning and mobile terminal, which aimed at investigating the feasibility of its utilization on in-home dental healthcare. They developed a smart IoT based dental device to perform the image acquisition of teeth. An automatic diagnosis model trained by MASK R-CNN was developed for the purpose of detecting and classifying seven different dental conditions, which included dental caries, cracked tooth, dental fluorosis, dental plaque, dental calculus, periodontitis and tooth loss, the recognition rate was 90.1%, 94.1%, 95%, 100%, 98.1%, 94.3% and 98.4%, respectively.

Vellappally et al [10] evaluated patients' oral health by collecting dental X-ray images followed by IoT based xeno-genetic spiking neural network analysis. Tooth structure, gaps/spaces between teeth and positioning of incisors, premolars, molars was examined efficaciously by IoT analysis. This method of effective extraction of oral features aided in increased oral health prediction rate. The technique was 97.115% accurate, which was comparably higher than other methods (Table 1).

Kishen et al [11] developed an IoT based fibre optic biosensor (FOBS) for detecting and tracking mutans streptococci activity in human saliva. FOBS utilizes fibre optic evanescent wave spectroscopy to detect the bacterial mediated biochemical reaction using a photosensitive indicator. Therefore, IoT based sensors can also be used for detection and monitoring of various pathogenic oral microorganisms.

Strain-gauge transducers, piezoelectric transducers and pressure type of transducers are commonly used in various commercially available bite force recording devices. The bite force is a prime factor in establishing the functional state of the masticatory system, which comprises of jaw muscles, teeth and joints. Factors like the positional offset of teeth and mandible, age, gender, load on the periodontal tissue can influence the generated bite forces. [13]

In an in vivo study [14], IoT based intraoral sensor named fibre Bragg grating (FBG) sensor was attached to oral appliance named bite force measurement device (BFMD) and it was used for evaluation of bite force measurements. BFMD was a noninvasive intraoral device that helps in transducing the bite forces exerted at occlusal surface of teeth into strain variations on a designed metal plate. Strain variations were attained by the developed FBG sensor bonded over it. BFMD helps in the adjustment of the distance between the biting platform, thereby capturing the maximum voluntary bite force at three different teeth sites (incisor, premolar and molar) (Table 1). Bruxism refers to grinding or tight clenching of the upper and lower teeth, which on long term leads to tooth wear (attrition), dentin hypersensitivity, headaches, orofacial pain and temporomandibular joint problems. [15] Thus, IoT based sensors can also be advocated in future for recording bite force measurements in cases of bruxism, trauma from occlusion, to assess the efficacy of various prosthesis around teeth and implant sites, to study about deformities and pathologies of the masticatory system and in temporomandibular joint disorders. [16]

A dental implant is a biocompatible device, surgically placed into mandibular or maxillary bone, which supports a prosthesis thus allowing the replacement of the teeth loss due to caries, periodontal disease, injuries or other reasons.[17] The virtue of dental implants is definitely associated with proper osseointegration process. Implant failures are of biologic, mechanical/prosthetic, surgical and aesthetic types. Irrespective of high implants success rates, literature reveals a notable incidence of mechanical/technical complications that is due to unfavourable loading or as a result of high stress concentrations.[18] More prevalent mechanical failures include abutment and prosthetic screw loosening and fracturing, microdisplacement of the prosthesis and abutment-implant connection. Sannino et al [19] developed an IoT based integrated wireless and sensing technology to detect microdisplacements for implant supported prostheses to prevent mechanical implant failures.

Table 1 : IoT Applications in Dentistry

Applications	Features	References
1. Diagnosis—as a smart diagnostic aid	Smart dental health IoT system based on intelligent hardware, deep learning and mobile terminal for detection of caries, periodontitis, cracked tooth, dental fluorosis and tooth loss	Liu et al.[9]
	IoT based xeno-genetic spiking neural network analysis for evaluating oral health	Vellappally et al.[10]

2. Microbiological evaluation/ bacterial detection	IoT based fibre optic biosensor (FOBS) for detecting and tracking mutans streptococci activity in human saliva Graphene based IoT nanosensor for remote monitoring of pathogenic bacillus	Kishen et al.[11] Mannoor et al.[12]
3. Bite force measurements	IoT based intraoral sensor attached to oral appliance for evaluation of bite force measurements	Padma[14]
4. Mouthguard invaded biosensors	Wearable noninvasive mouthguard biosensor for purpose of noninvasive human salivary lactate levels monitoring IoT sensor mouthguards coupled with miniaturized instrumentation electronics for detecting salivary uric acid level	Kim et al.[15] Kim et al.[16]
Dental implantology	IoT based integrated wireless and sensing technology to detect microdisplacements for implant supported prostheses	Sannino et al.[19]

4. APPLICATIONS

4.1. Oral health

Smart toothbrushes can be used to gather patient data regarding their brushing activities. These toothbrushes come embedded with a plethora of technologies such as cameras, pressure sensors, and much more. The inbuilt camera is used to track the brushing activity. It can replicate an oral examination procedure during the routine brushing procedure. The dentist can examine the teeth of the individual from the data captured by the camera during the brushing activity. Additionally, pressure sensors attached can be utilized to determine if the brushing process is carried out properly. It can measure whether the right intensity or force is applied and can alert the user in case of any deviations. All the data can be shared with the dentist in real-time and thus increases the preventive care process. Most of the dental issues are caused due to improper brushing and thus with the help of smart toothbrushes, the problem can be easily solved.

4.2. Dietary/ smoking habits affecting general health

A very useful application of IoT for dental care comes in the form of tooth-mounted implants. These implants can be placed on the surface of the tooth or part of artificial denture or crown or dental endoseeous implant. The implants can be used to monitor the food intake of individuals. The data collected is then shared with the doctor in real-time.

4.3. Management of Bruxism

The biggest challenge in the management of bruxism is the fact that the patient does not give any subjective input about the prevalence and frequency of the habit. The grinding of teeth often takes place in the patient's sleep and thus the patient is not conscious of the habit. Mouth guards do act as a preventive measure to treat bruxism but the use of IoMT in the form of pressure sensors attached to the mouthguards can turn out to be a more effective way to treat the condition. The device could identify the areas of teeth which are most affected by the clenching and grinding. Identification of tooth surfaces that are subjected to the maximum amount of pressure can help dentist devise effective treatment and restoration plans. The data so gathered has the potential to help find a cure for bruxism.

4.4. Prevention of cardiac diseases

In Cardiac diseases high levels of C-reactive protein (CRP) and salivary immunoglobulins (Ig A) can be monitored in salivary samples. The levels of theses markers indicate the risk of heart attack and also a determinant of the stage of cardiac disease. IoT device attached to a tooth or prosthetic tooth or denture evaluates cardiac condition through these markers give live feed on a mobile application to the treating physician. So any medical emergency such as cardiac arrest can be avoided or immediate actions can be taken to prevent loss of life.

CONCLUSION

As the world is evolving towards being 'smart', it is important to handle things in a 'smart' approach in dentistry as well. IoT has significant impact in Healthcare to provide need based services from past one decade, so it is the time for revolution in dentistry. IoDT can play a vital role in collection and monitoring of patients' data for oral health care, eventual risk assessment and further research.

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