

# Internet of Dental Things (IoDT), Intraoral Wireless Sensors, and Teledentistry: A Novel Model for Prevention of Dental Caries

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## Research Article

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# Abstract

Dental caries is a complex, multifactorial, transmissible biofilm-initiated oral disease, which results in loss of tooth structure. Oral microbial flora, pH of biofilm, consumption of carbohydrates, and oral hygiene are few of those major factors, which cause dental caries. However, it is possible to monitor those cariogenic factors with the help of new technology, and that will result in the prevention and early detection of dental caries. Internet of Dental Things (IoDT) is an advanced cloud-based digital technology, which could be successfully used in this area. Our goal is to generate such a technology-based model. This paper proposes a novel innovative model, which is based on Internet of Dental Things, intraoral wireless sensors and tele dentistry, which will achieve prevention and detection of dental caries in its initial stages.

## 1. Introduction

Dental caries is one of the most prevalent diseases worldwide even today [1]. Dental caries occurrence is still elevated in economically developed, developing and underdeveloped nations [2]. It is an infectious, micro-bacterial biofilm-initiated disease, which is reversible in the incipient stages, caused by interaction between the biofilm bacteria on fermentable carbohydrates, which leads to acid demineralization and proteolytic destruction of hard inorganic and organic tissues of tooth; this disease commonly occurs in all age groups of patients due to imbalance in demineralization and remineralization process [3], this process is shown in figure 1.

Figure 1 illustrates the action of biofilm bacteria on fermentable carbohydrates, which causes the changes in plaque pH over time. The critical pH of enamel is 5.5, while for dentin it is 6.2, where hydroxyapatite crystals breakdown and demineralization process of normal tooth structure starts and finally results in dental caries. While fluorides usage and biofilm control measures increase the pH of biofilm, which results in remineralization of the carious tooth structure in its initial stages.

In this paper, we have emphasized on effective implementation of a novel model for improvement of prevention and management of dental caries. This innovative caries prevention model is based on advanced IoDT technology, intraoral wireless sensors mounted on the dental appliances and tele dentistry application. This technology-based model provides insights in control of caries causing factors and monitors those factors in oral cavity.

This paper is formulated into five sections as described below. The first section introduces dental caries as a prevalent health problem in world today, and this section also narrates, how caries process occurs on tooth surface. The second section overviews the details of dental caries issue in society plus, it also describes the etiology of dental caries. The third section outlines new innovative IoDT based Dental-Care Model for prevention and management of dental caries. The fourth section discusses conceptual IoDT based Caries Prevention Model in detail. This fourth section also outlines data monitoring process as well as enumerates advantages of this hi-tech model. The fifth and last section describes about conclusions in detail.

## **2. Dental Caries As A Predominant Health Issue In Society**

Dental caries is a prevalent health problem, which affects all patients' age groups. A current review on epidemiological data shows, there is a significant increase in percentage of dental caries prevalence in the world in primary as well as in permanent dentition [4]. According to 2000 American report, the children (between 5-10 years) show prevalence of dental caries more than 52% - 55% [5]. On the other hand, in teenager and young adults, the occurrence of dental caries is more than any other diseases seen in that age group e.g., asthma and hay fever.

Dental caries affects masticatory function, esthetics, psychosocial health, self-esteem, as well as well-being of patient [6]. However, it is the most commonly found oral disease in our society.

### **2.1 Etiology of dental caries**

Many factors affect occurrence of dental caries in patients. Frequency of intake of fermentable carbohydrates [7, 8], oral hygiene measures for biofilm control [9], pH, as well as bacterial flora in the biofilm formed on the tooth surface in oral cavity (ex. Streptococci Mutants and Lactobacilli) [10] are few of those etiological factors. Fermentable carbohydrate diet compromised oral hygiene measures causes a higher occurrence of this biofilm initiated oral disease. Figure 2 illustrates etiology of dental caries and different factors influencing the occurrence of dental caries.

### **2.2 Traditional models for prevention of dental caries**

Conventionally caries prevention model is based on fluoride susceptibility, dietary regulation of fermentable carbohydrates, and optimal oral care achievements by removal oral biofilm as well as oral hygiene measures. But it is important to introduce modern measures in addition to those primary prevention factors into a new context.

Different caries prevention models are discussed till date.

Svante Twetman (2018) has introduced usage of probiotics in order to achieve caries prevention. Probiotics cause biofilm disruption and promote microbial diversity by growth of good healthy flora in oral cavity [11].

Kim Kutch (2013) has introduced "Caries management by risk assessment" (CAMBRA) model. This model has assessed common disease pattern of progression of caries and evaluated their therapeutic strategies for the usage of model to practicing dentist [12].

## **3. New Innovative Iodt Based Dental-care Model For Dental Caries Prevention And Management**

It is common to introduce and implement the innovative health care model for prevention and management of chronic diseases [13].

Caries is one of the common plaque-initiated oral diseases, which arise with lifestyle changes and compromised oral hygiene in children and adults [14,15]. Caries management procedures are expensive and time consuming for patient itself and to overall society [16].

Currently, caries management by risk assessment method is used in clinical practice with application of CAMBRA based principle on the caries balance/ imbalance model, but this method is not simple and easy to apply [17].

Hence, it is necessary to introduce new advanced digital-based caries prevention and management model, which could be easily used at community level, plus it should be cost effective, as well as it should be effectively used by patients continuously and regularly on daily basis.

Advanced caries management model should be such that, firstly it should cause prevention of dental caries, secondly it should help in early detection of incipient dental caries; lastly it should be a great tool in risk-assessment procedures.

However, it is an innovative approach to introduce dental caries prevention model based on Internet of Dental Things (IoDT). Internet of Things is an advanced cloud based digital innovation in science and technology today; medical field is already invaded by this web- based technology [18].

Internet of Medical Things is used successfully in prevention and management of chronic diseases by monitoring patient's daily health- status through wearable sensors, monitoring wireless devices [19]. We have already introduced IoT application in dentistry as IoDT (Internet of Dental Things) in our previous paper [20].

It is already proven, that future disease detection and monitoring will be based on primarily "mobile phones plus its wireless network, cloud computing technology based on Internet of things, and direct automation process" [21].

Thus, we tried to monitor caries cariogenic factors with intraoral sensors. Figure 3 shows IoDT based novel caries prevention model.

## **4. Conceptual Iodt Based Caries Prevention Model Overview**

The conceptual IoDT based model is inspired from the use of Internet of Medical Things (IoMT) in monitoring of chronic systemic diseases e.g., Diabetes mellitus [22], Parkinson's disease [23,24], and Chronic obstructive pulmonary disease [25].

In this conceptual model, there are four important factors: data, information, knowledge, and technology [20]. The main aim of this model is to achieve a perfect caries-prevention model, which could utilize available data, and information in combination with deeper knowledge that is used along with digitization and application of new technology. Figure 4 shows main factors contributing in IoDT based

conceptual caries prevention model. Patient data, application of knowledge, available information and technology are very crucial key factors in this model.

This IoT based caries prevention model could be easily applied at the community dental care level.

There are few elements, which are extremely important to consider during application of this model.

**A. Monitoring system design:** It is very important that uninterrupted disease monitoring of patients should be possible with patient's personal phones/ tablets through an app. In monitoring appliances, oral factors will be monitored with the help of intraoral sensors [26]. Those intraoral sensors will be incorporated within oral appliance, which patients can easily use on daily basis in the oral cavity. The design of those appliances with sensors should be such that continuous monitoring of patients will be possible [27]. Those data monitoring sensors will be small in size, weightless, biocompatible to oral tissues, and easy to use.

**B. Advanced patient monitoring system:** This model consists of advanced clinical monitoring system, which assess different caries causing cariogenic factors in oral cavity with the help of Internet of Dental Things (IoT), smart phones/tablets, intraoral sensors, as well as tele dentistry. Internet of Dental Things is an internet-based advanced technology that is used efficiently in supervising patient diseases, prevention, and management of chronic diseases [28].

Sensor technology and cloud network plays a vital role in Internet of Things (IoT) technology. When data monitoring sensors are used in patient's body for tracking diseases, those sensors transfer data to patient's personal mobiles phones /tablets, and forms sensor technology associated "Body-Area Network" [28]. Today this advanced sensor technology and smart phones are used in collection, monitor, transfer, and analyze data for disease prevention and diagnostics purpose.

Tele dentistry is also an advanced tool based on telecommunication technology and is used effectively for patient consultation as well as to provide dental management advice across different geographic areas [29].

Clinical studies and evidence show that, it provides great help in diagnosis and detection of dental caries [30], oral health screening [31], as well shows similar diagnostics outcome as real patient examinations [32].

**C. IoT and technology-based education:** This model could easily provide oral health education, technology derived monitoring training to dentists; in addition, it can also allow collection /transfer of information, and customization of technology [33].

**D. Patient self-oral care monitoring and management:** Patient could be easily monitored for their oral health care on daily basis.

**E. Data analysis storage and further research:** Technology used in this conceptual model consists of following cutting-edge technology: Internet of Dental Things (IoDT), Wireless sensors, and Tele dentistry. This technology helps in analysis of data and research. Figure 5 enumerates technology used in this caries prevention model.

In this model, we could monitor patient's oral health through wireless sensors, electronic devices by constant supervising different oral cariogenic factors. These wireless sensors are connected to cellphones or tablets through a mobile app to carry out continuous, uninterrupted monitoring activity. Figure 6 shows monitoring process of caries causing factors with the help of IoDT, while figure 7 illustrates IoDT based monitoring by dental specialist/dentist.

#### **4.1 Data Monitoring Process in prevention of dental caries model**

The data monitoring process in IoDT based model will be carried out in three different stages; this process is described in figure 8.

**1. Oral data collection stage:** In this first step, intraoral sensors are used to monitor different factors like pH of oral cavity, presence of biofilm, temperature of oral cavity. The generated data is collected continuously and interruptedly from patients.

**2. Data Transfer stage:** This collected oral care data gets transferred to the cloud server through mobile phones or tablet app.

**3. Analysis of data and storage:** IoDT application, Artificial Intelligence (AI) and tele dentistry carries out the analysis of data and storage.

#### **4.2 Advantages of IoDT based caries prevention model.**

This high-tech model has the following advantages,

- I. It is Actual Time - Data control system that assesses the patients' caries contributing factors.
- II. This model could be used for larger group of patients. It could be easily applied at community level with help of cloud server.
- III. It decreases the oral care cost to the patient by prevention of disease [32].
- IV. Analysis of cariogenic factors and prevention of dental caries are possible 24X 7.
- V. It will also increase patients' interest in oral health care.
- VI. It will provide alerts and data all the time through sensors.
- VII. It could be the best tool for physically challenged and chronically ill patients.
- VIII. It will not only cause prevention but also early detection of oral diseases.

The following figure 9 highlights advantages of IoDT based caries prevention model.

## 5. Conclusions

Dental caries is a complicated, multifactorial disease, which could be prevented or early detected by the new technology along with conventional measures. Many etiological factors contribute to the formation of dental caries like, dietary intake of carbohydrates, oral biofilm, pH of biofilm, fluoride usage, and routine oral care measures. These factors could be easily tracked every single day by intraoral sensors, new generation of app-integrated smart phones, IoT and cloud server. Intraoral sensors mounted on appliances are easily used to monitor cariogenic factors e.g., biofilm pH, presence of biofilm, temperature of oral cavity. This data is collected continuously from patient's oral cavity and transferred to the cloud server through mobile or tablet app. Finally, analysis of data is carried out by the IoT, artificial intelligence and tele dentistry.

IoT is an advanced technology, which is introduced in prevention of dental caries. We have successfully conceptualized this hi-tech model in this paper, which works on IoT, intraoral sensors, tele dentistry. This IoT based caries prevention model could be easily used in clinical monitoring process and oral data collection step. In addition it also provides analysis of the collected data, causes prevention and early detection of dental caries. This model could be easily applied at community level.

## Declarations

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**Availability of data and material** (Not applicable)

**Code availability** (Not applicable)

**Authors' contributions** (All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Smita Salagare. The first draft of the manuscript was written by Smita Salagare and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.)

**Ethics approval** (Not applicable)

**Consent to participate** (Not applicable)

**Consent for publication** (Not applicable)

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Internet of Things (IoT) Based Design of a Secure and Lightweight Body Area

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## Figures

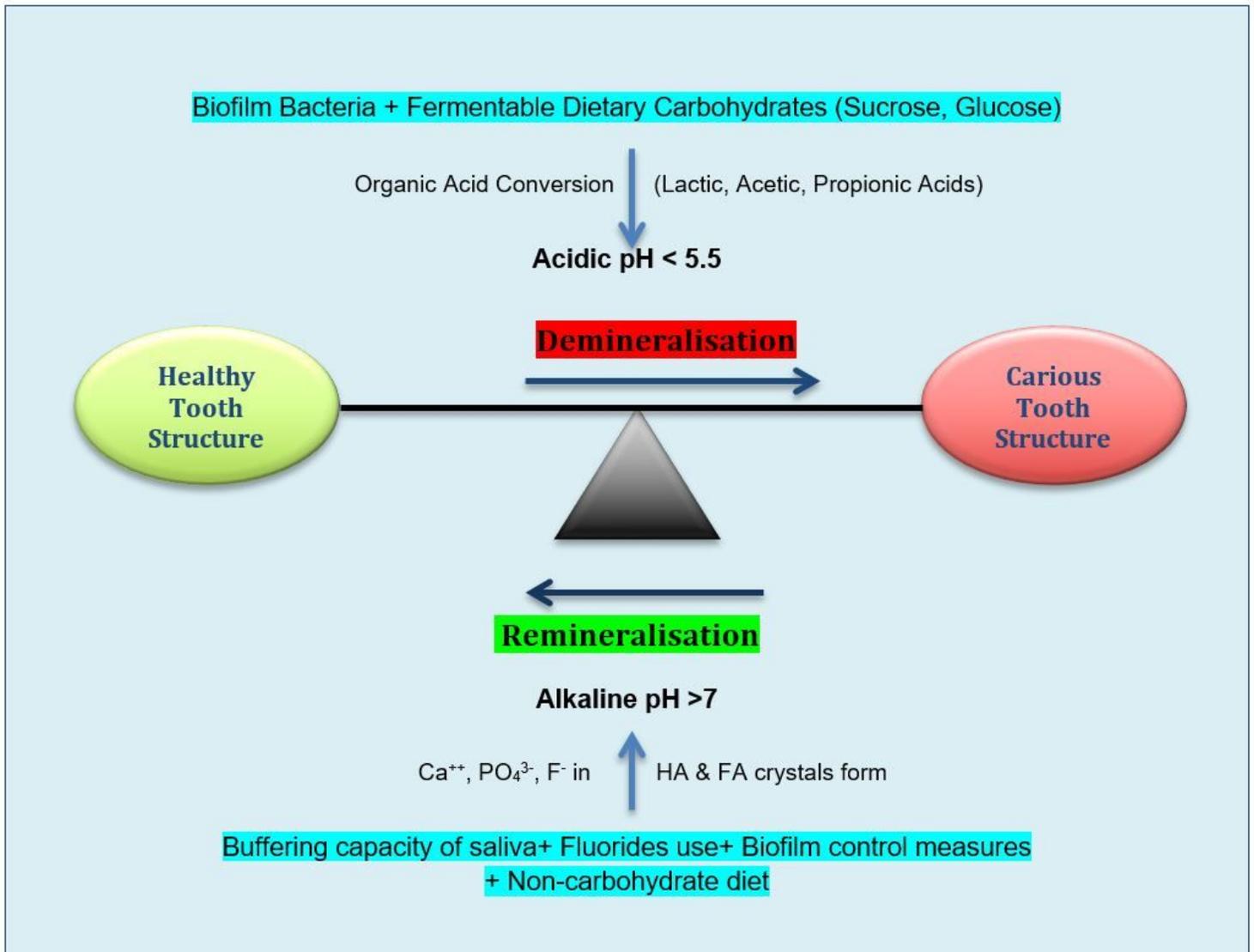
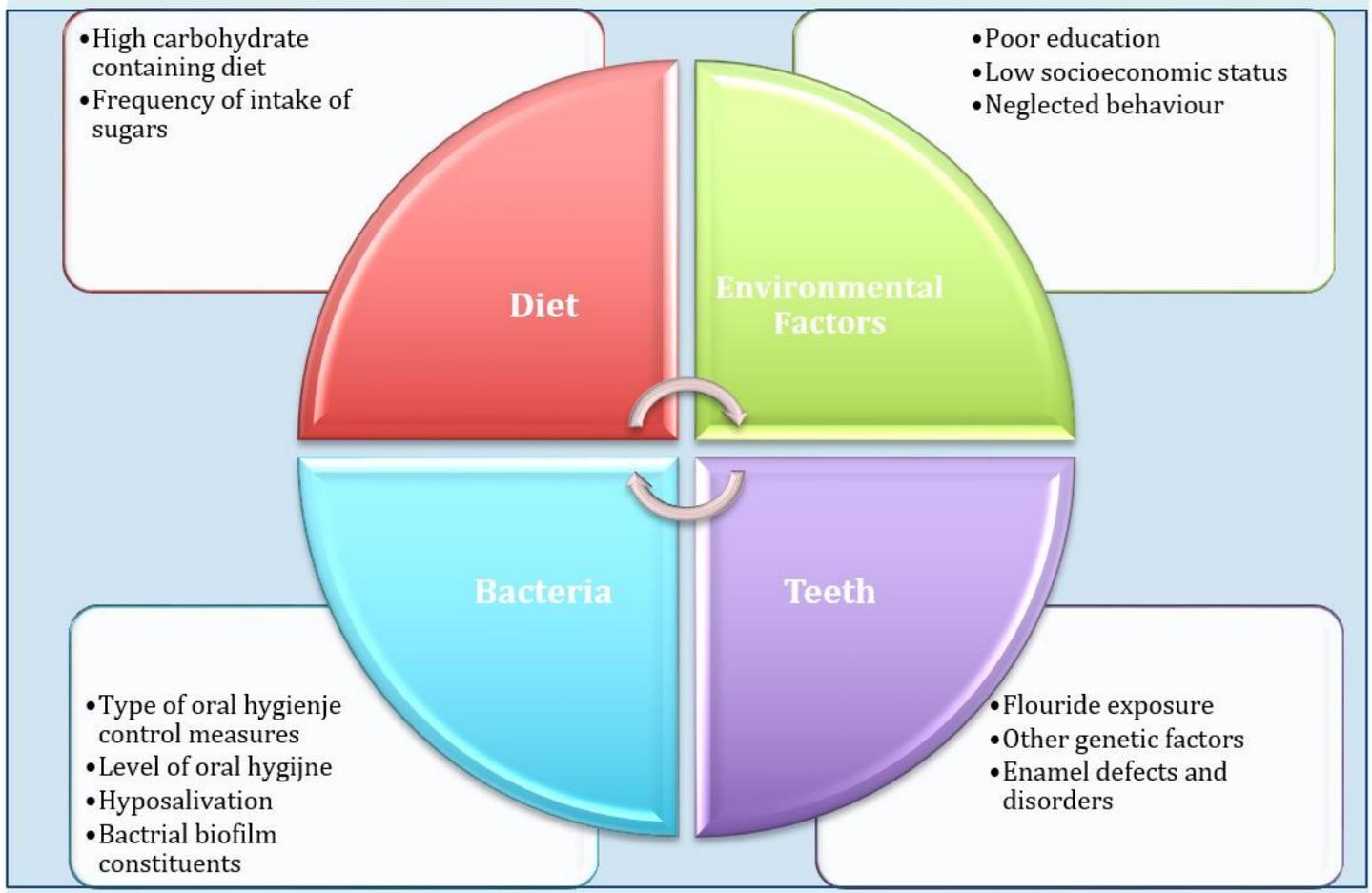


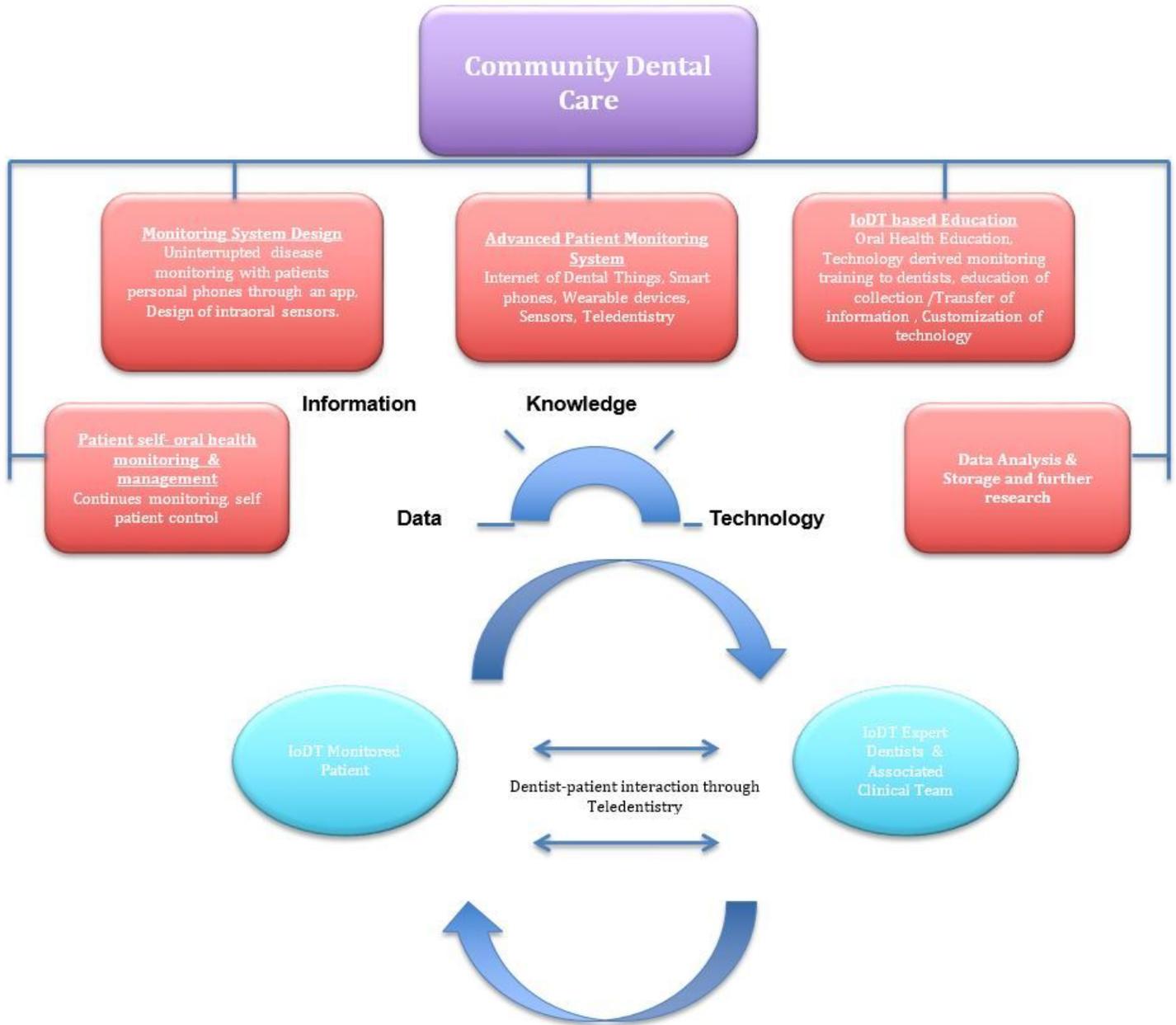
Figure 1

Demineralization and Remineralization Process in Dental Caries



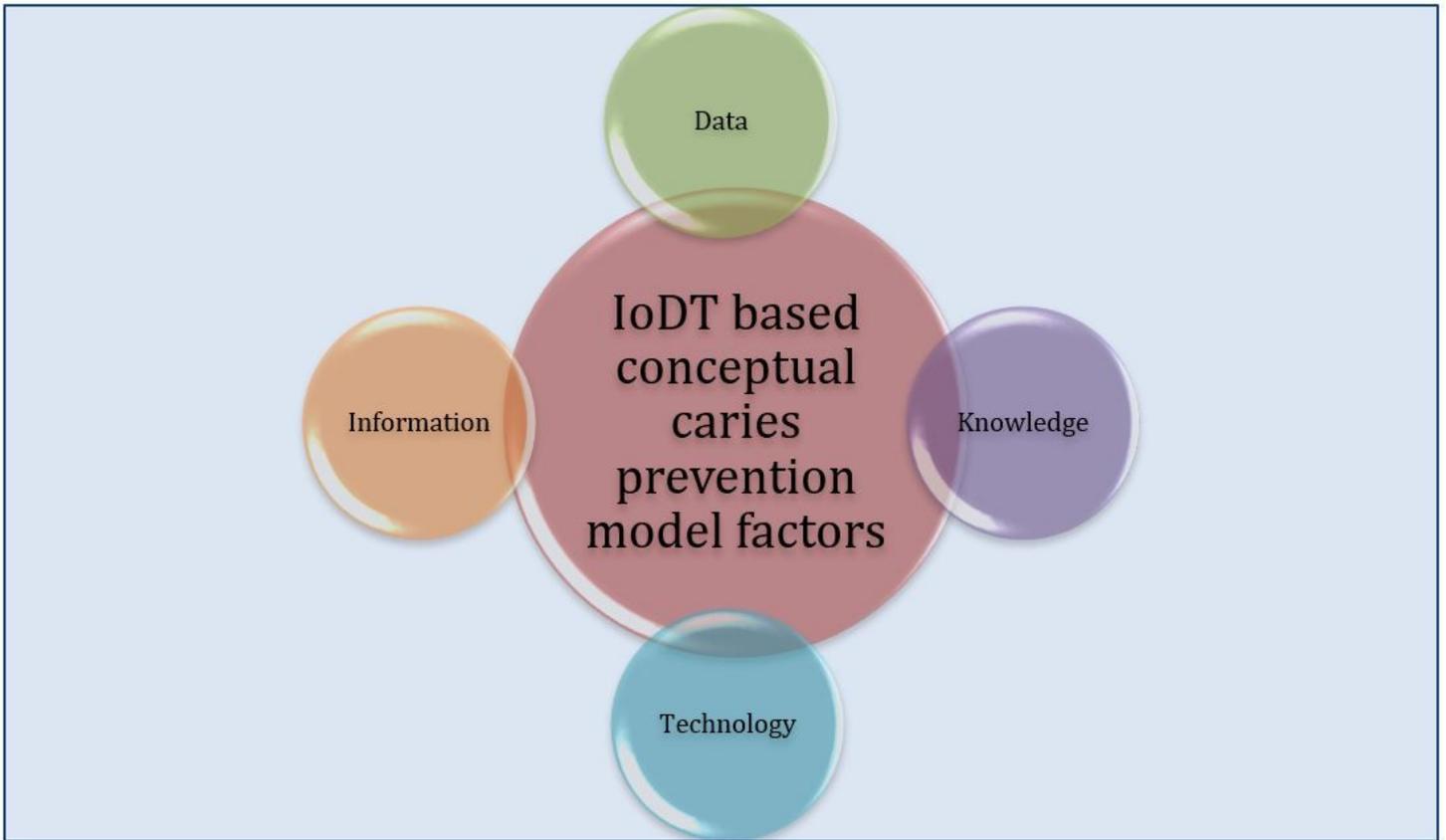
**Figure 2**

Etiology of Dental Caries



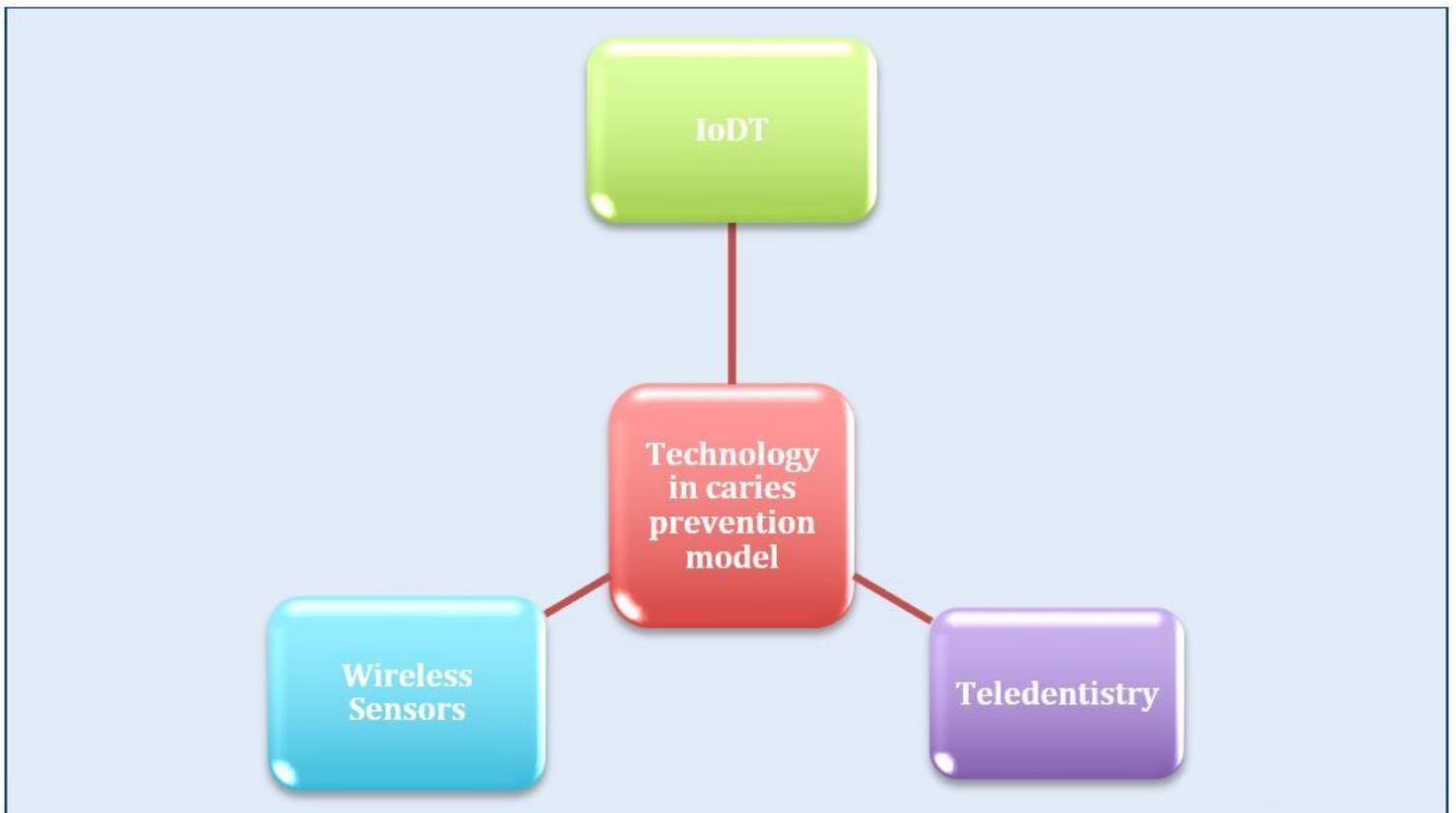
**Figure 3**

Internet of Dental Things based Novel Caries Prevention Model



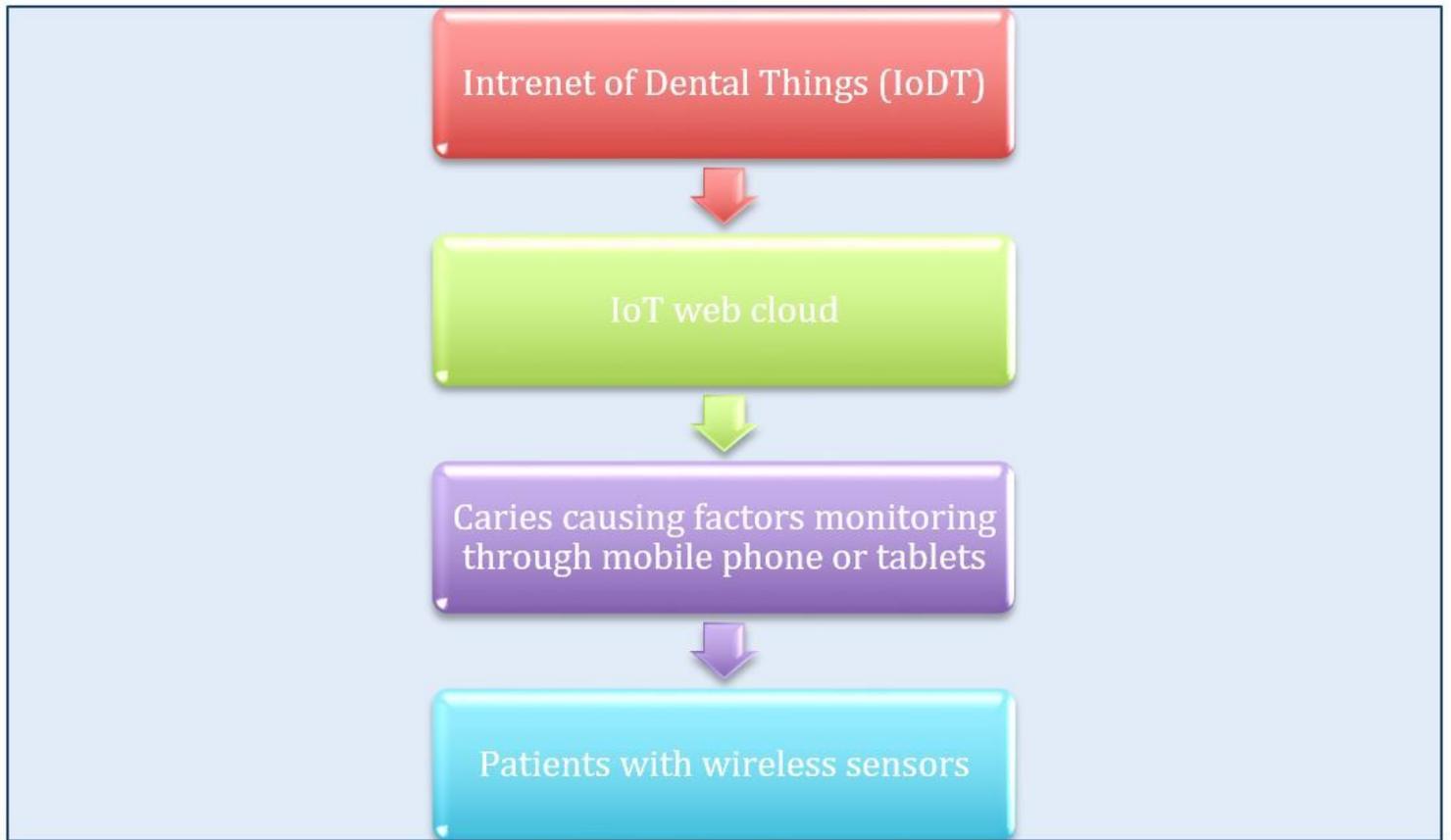
**Figure 4**

IoDT based Conceptual Caries Prevention Model Factors



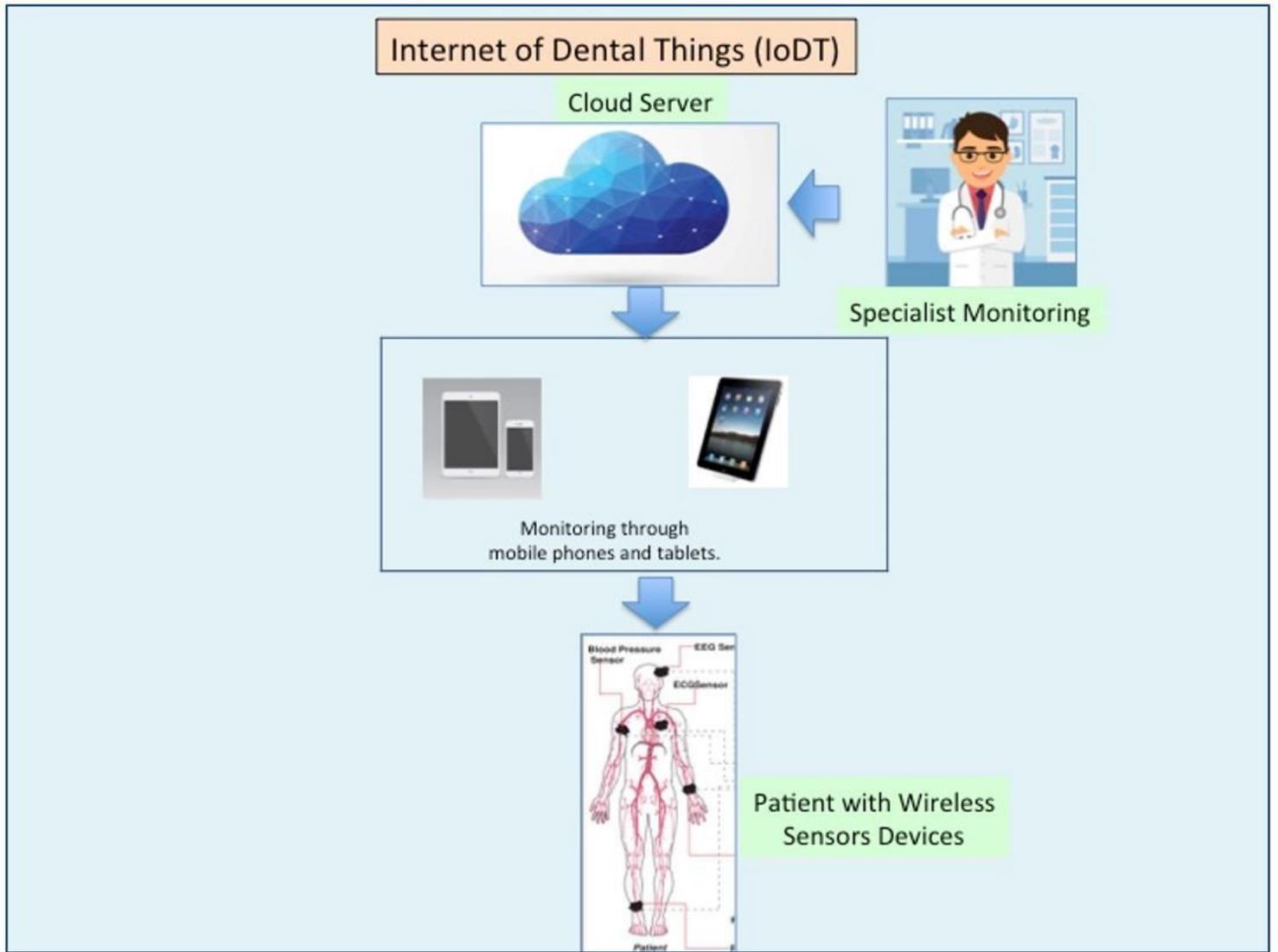
**Figure 5**

Technology incorporated in Caries Prevention Model



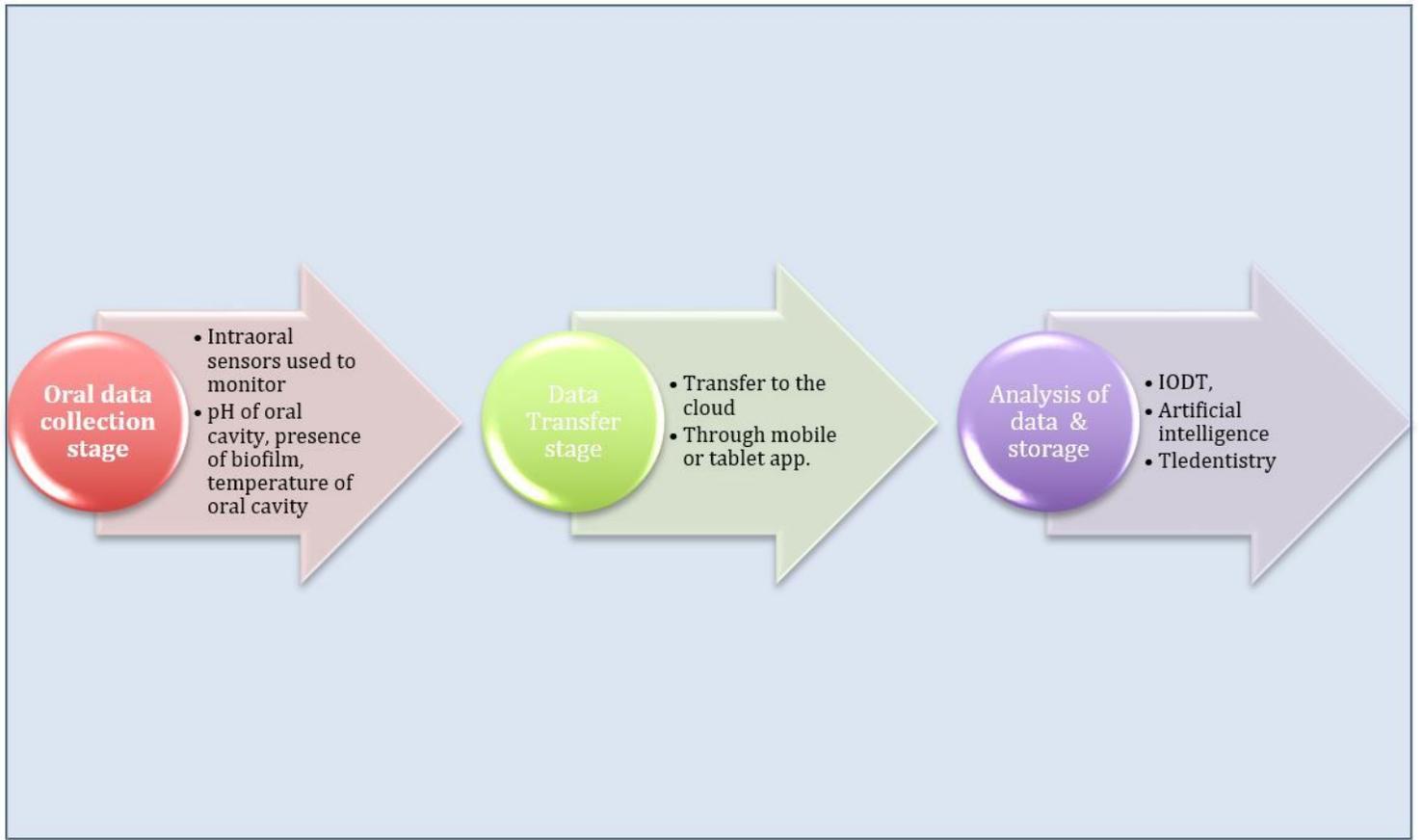
**Figure 6**

Monitoring process of caries causing factors with use of IoDT.



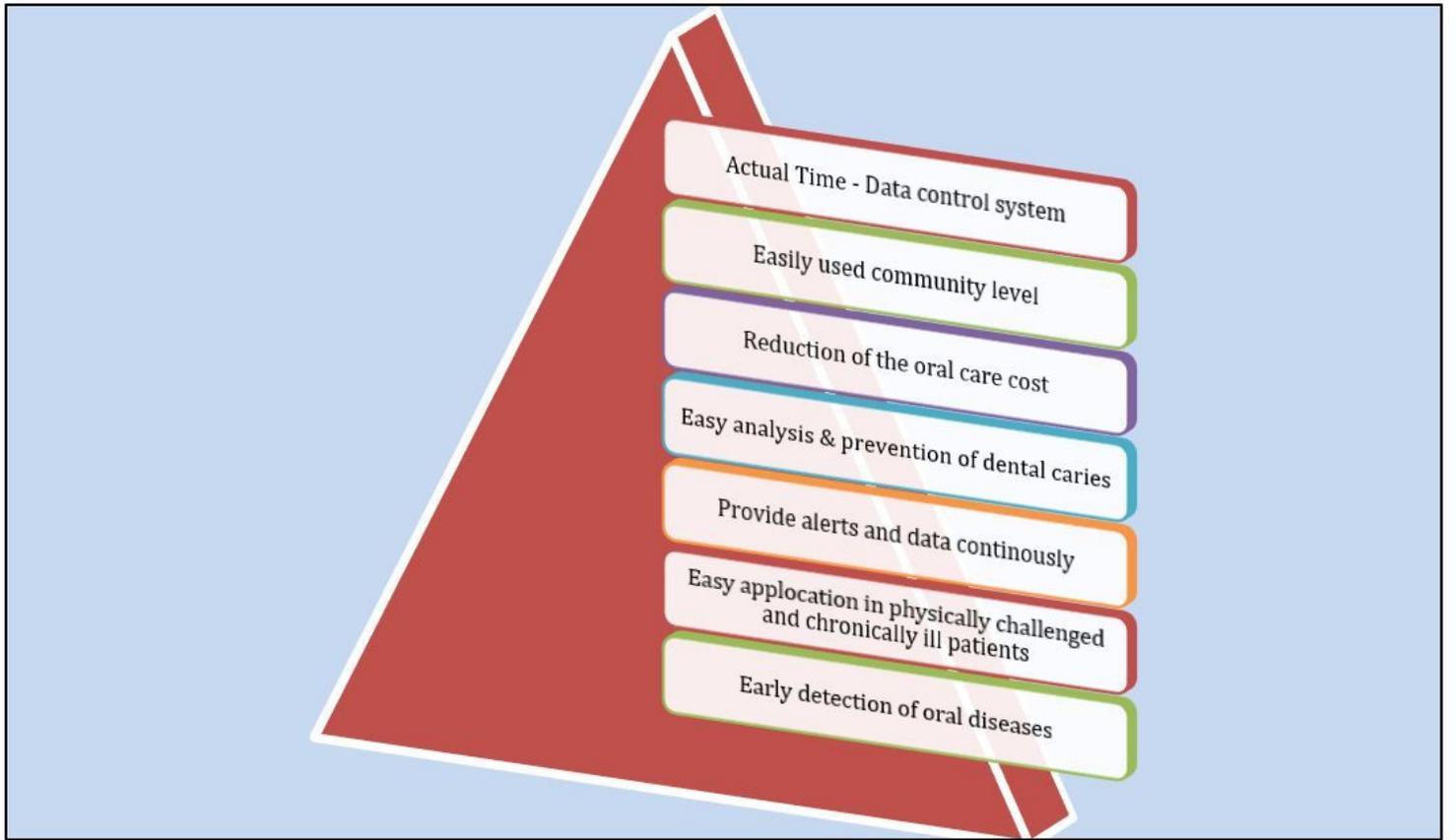
**Figure 7**

IoDT based monitoring by IoDT specialist/Oral health care staff.



**Figure 8**

Data Monitoring Process in prevention of dental caries model



**Figure 9**

Advantages of IODT based Caries Prevention Model