SENSORS AND TELE-ORTHODONTICS

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Abstract

The world of orthodontics and dentistry has come a long way since the invention of braces. Today, technology is revolutionizing the field with advanced sensors and dental tele-monitoring systems. These new tools are changing the way we approach oral health by providing real-time data that can be used to diagnose and treat issues faster than ever before. By using sensors to monitor the position of teeth and jaws, orthodontists can provide customized treatment that is tailored to the individual needs of each patient. This technology also has the potential to improve patient compliance with treatment regimens by providing real-time feedback on progress.Secondly, the AI-powered tools can offer treatments that are more personalized, efficient, and accurate than ever before. With the ingress into the techie-era, there is a constant need for evolution in both professional and personal front and the knowledge regarding the same is the need of the hour.

Keywords: Sensors, Dental monitoring, Teleorthodontics

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1. Introduction

With advancements in technology, traditional braces and aligners are giving way to sensor-based treatments that promise greater precision, comfort, and efficiency. These cutting-edge devices use sensors and artificial intelligence algorithms to monitor tooth movement and adjust forces accordingly. As a result, patients can enjoy faster treatment times with fewer office visits while achieving optimal results.Sensors have also emerged as a boon in detecting the compliance of the patient especially in removable functional appliance.In recent years, there has been an increasing interest in teledentistry, particularly in the field of orthodontics. Teledentistry is the combination of telecommunications and dentistry to provide dental care across long geographic distances by utilising artificial intelligence[1]. It involves the digital exchange of clinical information between a patient and a health-care center or provider. With remote treatment-monitoring software, orthodontists can monitor their patients' progress remotely, without the need for in-person appointments. This can be especially beneficial for patients who live far away from their orthodontist.

Aligners have taken over the present era in orthodontics with an upsurge in the demand for esthetic treatment over traditional braces. The media, digital marketing and computers have rooted its dominance in success of orthodontic practice. This marks the need to incorporate the digital innovations and their knowledge is essential for better practice

Tele Dentistry:

Teleorthodontics allows orthodontists to extend the usefulness of telehealth and facilitate orthodontic consultation and treatment via information technology and telecommunications[2].Teledentistry can be used by both orthodontists and general dentists to provide consultations for orthodontic cases. This type of technology has been investigated for its ability to increase patient satisfaction and make it easier for practitioners to create referrals between patients and their respective dental care professionals. With digital technologies, orthodontists can create custom orthodontic appliances remotely[3].

The most common risk associated with tele-orthodontics is misalignment of the teeth during treatment. This can happen if the patient does not follow the instructions provided by the orthodontist or if the patient's mouth changes shape during treatment. Other risks include infection, gum disease, and tooth decay. Another concern with teledentistry is the potential for abuse. With the rise of DIY braces, there is a risk that patients may attempt to straighten their teeth at home, without the guidance of a trained dental professional[4]. This can lead to serious dental problems, including tooth loss and gum disease.

Dental Monitoring

The Dental Monitoring system[5]is the latest technology with knowledge-based algorithm that combines robotics and deep learning process with information systems that act like a semi-intelligent user.It combines tele-dentistrywith AI and enhance the doctor-patient interaction.It basically keeps a track of the patients tooth movement and gives an alarm in case of deviated tooth movements. The emergence of deadly covid-19 gave jitters to all medical fraternity with loss of thousands of lives. This corroborated the importance oftele-medical consultation and treatment and with this scientists from France came up with the application called-dental monitoring. The patient takes intra oral pictures with smart phone and a special scan box which is then transferred to the dentist for monitoring.The dental monitoring also keeps a track on aligner clincheck and weekly tooth movement.

Fig 1

A 3d scanning procedure called photogrammetry is used in different areas of medical and dental fields. Mobile phone camera an alternative to digital camera in photogrammetry was invented which is used to capture impressions for digitalization[6].

Sensor Technologies:

Flexible Monitoring Sensors:

Flexible wearable electronics[7] are sensor based devices which has integrated engineering into medical sphere. They are used in the health monitoring process to transform physiological information such as heartbeat, blood pressure, and joint bending into electrical signals. In orthodontics, FMS has is in its entry level in monitoring the muscle movements, tooth movement tracking and bacterial detection. Conventional electronic sensors are not suitable for monitoring physiological signals since they have low sensitivity and stretchability and are frequently constructed of metals or semiconductors. The flexible sensor has demonstrated exceptional biocompatibility and the real-time monitoring as compared to the traditional electronic sensors[8].

Advantages:

Biocompatible

One of the most significant advantages of FMS is their biocompatibility. Traditional electronic sensors are often constructed of metals or semiconductors, which can cause irritation or allergic reactions in patients. FMS, on the other hand, are made from biocompatible materials such as silicones and organic polymers. These materials are safe to use within the human body and do not cause adverse reactions.

Stretchability

FMS are highly stretchable, making them more comfortable to wear than traditional sensors. Traditional sensors are often rigid and can cause discomfort or even injury when worn for extended periods. FMS, on the other hand, are flexible and can conform to the shape of the body without causing discomfort. This makes them ideal for monitoring oral health, as they can be worn for extended periods without causing discomfort.

Lightweight

Another advantage of FMS is their lightweight design. Traditional sensors can be bulky and heavy, making them uncomfortable to wear for extended periods.

Accuracy

FMS are more accurate than traditional sensors, providing real-time monitoring of oral health. Traditional sensors can be limited in their ability to detect changes in physiological signals, such as tooth movement or bacterial growth. FMS, on the other hand, can detect even the slightest changes in oral health, providing dentists with real-time data to inform treatment decisions.

Disadvantages:

FMS are more expensive than traditional sensors, which can make them less accessible for some patients and dental practices. Another disadvantage is the complexity of the technology, specialized training and expertise to use effectively. Finally, there may be some concerns about the privacy and security of patient data collected by FMS

Types of Flexible Monitoring Sensors

There are several types of flexible monitoring sensors used in dentistry. Some of the most common types include:Strain Sensors, Pressure Sensors, and Temperature Sensors

Affinity based sensors:

These sensors work by utilizing advanced molecular recognition technology to detect and measure the slightest changes in tooth movement. It incorporates synthetic or biological capture agent on the surface to capture the specific biologically-relevant target[9]. Affinity-based sensors are typically made up of a small chip that is attached to a patient's tooth, as well as a handheld device that is used by the orthodontist to read the data collected by the chip. The chip is designed to recognize specific molecules that are present in the patient's saliva, which change as the teeth move.

Affinity-based sensors can be used to monitor the movement of a patient's teeth throughout the entire orthodontic treatment process, from initial alignment to final positioning. Additionally, affinity-based sensors can be used to monitor the effectiveness of other orthodontic treatments, such as braces and aligners. By providing orthodontists with real-time data about the movement of a patient's teeth, affinity-based sensors can help to ensure that treatments are working as intended and make adjustments as needed.

Sensor Application In Orthodontics:

Sensors In Diagnosis:

Dental imaging is standard clinical practice that is an important source of information for a variety of purposes. Facial soft tissue images are important records in orthodontics for diagnostic processing, treatment planning, and outcome analysis. Depth sensors, long used in 3D scanners, gaming systems (such as Microsoft Kinect), and more recently incorporated in laptops and smartphones and can be used for 3D reconstruction[10]. These sensors are resilient to different lighting conditions (day and night, with or without glare and shadows), outperforming other types of sensors. The depth

sensor on the front of the device has a short range and can identify and map hundreds of landmarks in real time. They are mainly used to recognize faces and create 3D images. Its primary use is biometric security and facial recognition in smart phones which has extended its arena in facial and intraoral scanning procedures in orthodontics.

Wearable orofacial technology

A wide variety of printed flexible and MEMS-based silicon sensors are used in the prototypes for healthcare applications. For healthcare applications, there are basically two types of sensors. One of them comprises of surface attached sensors that are adhered to the body. These textile-based on-body wearable sensors are used to monitor the intended application comfortably. These on-body sensors have a few benefits, including easy attachment and non-invasive sensing capabilities. The second category of wearable sensors comprises prototypes that are implanted inside of the body. The implanted type of sensors is effective in evaluating deep seated and targeted application in real-time[11].

Sleep sensors:

Sleep tracking and identifying the sleep pattern is crucial for OSA patients and. Polysomnography is the gold standard for OSA. Due to its complexity and hospital based setup, it is difficult to monitor the patient overnight. The compliance also reduces in such cases. Polygraphic home sleep apnea tests are an alternative, which use a limited number of detected signals and may be less expensive and more effective in some populations. It can also be used to do overnight recordings similar to PSG at home. It uses sleep senosrs to monitor the sleep activity overnight and record the readings which can be evaluated by the doctor in the morning. There is also multiple-sensor incorporated together in the latest innovation to assess the sleep activity. Excellent patient satisfaction and cost-effectiveness were observed in a recent randomised controlled clinical study of a machine learning-based intelligent monitoring system (MiSAOS intelligent monitoring) intended to increase CPAP compliance in patients with OSA[12]. Recent invention called sunrise sensors is a small button shaped hardware placed on the chin by the sleep therapist to monitor the MM sleep patterns[13]. The collected data overnight is stored in cloud based infrastructure that can be communicated via a smartphone application.

Sensors in monitoring jaw movement:

Accelerometers: Accelerometers are able to measure the acceleration of the jaw and can be used to track things like chewing patterns or bruxism (teeth grinding). However, it is difficult to calibrate accurately and it is expensive..

Magnetometers: Magnetometers measure the magnetic field around the jaw and can be used to track things like tongue position or lip closure. They are generally more affordable than accelerometers, but can be less accurate.

Gyroscope: These sensors can measure the axis of rotation of the jaw bases and predicting any abnormalities in roll, pitch or yaw[14]

In order to measure jaw motion, a miniaturized wireless inertial measurement unit (WB-3) was proposed, which consists of a three-axis gyroscope, three-axis accelerometer, and three-axis magnetometer[14]. With the updated version, WB-4, jaw motion was measured using nine-axis inertial sensors (miniaturized accelerometers, gyroscopes, and magnetometers). Due to its reduced weight and size and Bluetooth module for wireless communication, the WB-4 can be easily attached to the mandible without any physical restrictions.

Bite Force Analysis

In order to measure bite force, a variety of sensitive electronic devices are in use[15]. These devices use pressure sensors to convert force into electrical energy, and they can be categorized into strain gauge transducers, piezoelectric transducers, piezoresistive transducers, and pressure transducers.These pressure sensors are placed on the surface of the teeth or along with intraoral splints[16] can detect changes in the pressure applied when biting down. This information can be used to detect abnormalities in the bite, such as bruxism (tooth grinding), and inform treatment decisions.

A strain gauge transducer is a pressure transducer that uses an elastic sensitive element and a strain gauge to convert the measured pressure into a corresponding change in resistance (Jansen van Vuuren et al., 2020). It consists of strain gauges, elastic elements and compensating resistors and is typically used to measure large pressures as in bite force[17].

Oral Health Monitoring

Dental health monitoring can be done by various biochemical sensors that can detect the specific compound leaching. Hidden caries has been reported to be strongly associated with the local release of volatile sulfur compounds derived from the degradation of sulfur-containing proteins by anaerobic bacteria. A preliminary diagnosis of hidden caries by monitoring the local emission of volatile sulfur compounds can be used as a screening tool as well as to monitor the progress of the dental health. The mouthguard sensors are a type of nanocomposite sensors with ZnO particles. The ZnO quantum dots serve as fluorescent probes and generally exhibit strong yellow fluorescence under ultraviolet (UV) light and undergo significant fluorescence quenching upon contact with volatile sulfur compounds (VSCs). In this way, hidden cavities can be easily detected and identified with the help of mouthguard sensors, contributing to the prevention, early detection and treatment of

cavities[18]. Temperature sensors can detect changes in temperature caused by inflammation, infection, or other oral health issues. This information can be used to diagnose and treat oral health issues before they become more serious.

Salivary sensors isa novel technique in the management of xerostomia which is a predisposing factor for various bacterial infection. A small micropressure capsule containing artificial saliva is inserted into a prosthesis which provides controlled release.[19]

Sensors In Treatment Planning:

Tooth Movement-

In orthodontics, FMS are used to monitor the movement of teeth during treatment[20]. Strain sensors are attached to the surface of the teeth and can detect changes in the strain of the tooth as it moves. This information is then used to adjust the treatment plan to ensure the best possible outcome.

Piezoelectric sensors are often used to measure the force exerted by the teeth on the brackets or other appliances during treatment. These sensors are very sensitive and can provide accurate data about the amount of force being applied. The difficulty in installation and cost factor are the shortcomings.

Strain gauges are another type of sensors that measure the amount of deformation that occurs in the bracket or appliance when a force is applied. This information can be used to determine the amount of force being applied and how it is distributed across the teeth. Strain gauges are less expensive than piezoelectric sensors but can be more difficult to install.

Optical sensors are another type of sensor that can be used in orthodontics. These sensors use light to measure the position of the teeth or brackets. Optical sensors can be very accurate but can also be expensive.

Splints-

Occlusal splints have variety of uses in orthodontics from TMJ.Intelligent occlusal stabilization splints with stress sensors are a promising approach to the diagnosis and treatment of bruxism. During the bruxism, the oocclusal/grinding force generated is detected and transmitted effectively by the embedded chips. The digital signals are converted to analog by a digital-to- analog converter and is transferred via a Bluetooth module a micro programmed control unit in a smartphone app. The abnormal signals give a vibratory alarm as a feedback to the bruxer as a remainder therapy. The biofeedback system was intended to produce a learned response and ultimately terminate the bruxism behaviour.

A stress sensor was integrated into a plastic-based occlusal stabilization splint and embedded in layer technology (sandwich method). The sensor system is mainly composed of pressure signal acquisition module, main control module and server terminal. Machine learning algorithms were used for occlusion force data processing and parameter configuration[21].

SENSORS IN COMPLIANCE INDICATION:

Patient compliance is critical to the success of orthodontic treatment, and non-compliance during treatment can adversely affect treatment duration[22]. The majority of sensors used in the oral cavity are temperature-sensing microsensors that sense and measure the temperature in the oral cavity when the device is in the mouth and convert the information into wear time. In addition to measuring temperature with a resolution of 0.1 °C, a microelectronic sensor (DentiTrac®, Braebon Medical Corporation , Ottawa, Ontario, Canada) are also listed.Special software (Braebon Medical Corporation, Ottawa, Ontario, Canada) is used to convert the data recorded by the sensors into wearing time[23,24,25]. Data from intraoral microelectronic sensors can be read at a special station or transmitted in real time to a smartphone via Bluetooth The safety and cytotoxicity of thermal microsensors have been successfully evaluated[26], confirming that they can be selected for objective monitoring of compliance.

Sensors in retention:

SMART retainers are tiny microsensors embedded in traditional orthodontic retainers[27]. The reduction in the size and power requirements of SMART sensors has increased the prospects of sensor usage in retainers. The Smart Retainer Environmental Microsensor automatically monitors the surrounding oral environment at pre-set intervals and saves the data or heuristic decisions about the data in an encrypted format. This information is later used by software in the orthodontist's office to determine how often and how long to wear the retainer[28].

Uses of sensors:

The use of sensors in orthodontics can provide a number of benefits,

- Increased accuracy in diagnosis and treatment planning.
- More precise monitoring of tooth movement.
- Reduced risk of complications during treatment.
- Shorter overall treatment time.
- Lower overall costs associated with treatment.

Risks 0f sensors:

There are a few risks associated with sensors in orthodontics.

- Breakage of the sensors
- Irritation to the gums or other tissues in the mouth.
- Inhalation or swallowing of the sensors.

- Leaching of certain components from the sensors
- Risk of the electronic components, including theprinted circuit board and the sensor/electrode being exposed to the oralenvironment.
- Biocompatibility issue in case of extended wear
- Sweat accumulation at the interface can cause aberrant signal transduction.
- Data encryption and privacy may become an issue

2. Conclusion

Sensors in orthodontics and dental tele-monitoring are revolutionizing the way dentists diagnose, treat and monitor their patients. With these advancements in technology, we can expect improved outcomes for our oral health as well as more efficient services for those seeking treatment. By utilizing advanced technologies the treatment planning and execution has become much easier.

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3. Reference

Palanivel J, D. David, Srinivasan D, et al. Artificial intelligence - creating the future in orthodontics - a review. J Evolution Med Dent Sci 2021;10(28):2108-2113,

Park JH, Kim JH, Rogowski L, Al Shami S, Howell SEI. Implementation of teledentistry for orthodontic practices. J World Fed Orthod. 2021 Mar;10(1):9-13.

Lo Giudice A, Ronsivalle V, Venezia P, Ragusa R, Palazzo G, Leonardi R, Lazzara A. Teleorthodontics: Where Are We Going? From Skepticism to the Clinical Applications of a New Medical Communication and Management System. Int J Dent. 2022 Feb 1;2022:7301576

Kravitz ND, Burris B, Butler D, Dabney CW. Teledentistry, Do-It-Yourself Orthodontics, and Remote Treatment Monitoring. J ClinOrthod. 2016 Dec;50(12):718-726.

Caruso S, Caruso S, Pellegrino M, Skafi R, Nota A, Tecco S. A Knowledge-Based Algorithm for Automatic Monitoring of Orthodontic Treatment: The Dental Monitoring System. Two Cases. Sensors (Basel). 2021 Mar 7;21(5):1856.

Abhijeet K, Mody E, Jei JB, et al. Mobile phone assisted 3D extra oral scanner for acquiring dental digital models - an innovative approach. J Evolution Med Dent Sci 2021;10(23):1815-1818, DOI: 10.14260/jemds/2021/375

Prasad, Sabarinath&Arunachalam, Sivakumar&Boillat, Thomas &Ghoneima, Ahmed &Gandedkar, Narayan &Diar-Bakirly, Samira. (2023). Wearable Orofacial Technology and Orthodontics. Dentistry Journal. 10.3390/dj11010024.

Zazoum B, Batoo KM, Khan MAA. Recent Advances in Flexible Sensors and Their Applications. Sensors [Internet] 2022;22(12):4653

Campuzano S, Yáñez-Sedeño P, Pingarrón JM. Electrochemical Affinity Biosensors Based on Selected Nanostructures for Food and Environmental Monitoring. Sensors. 2020

Thurzo A, Strunga M, Havlínová R, Reháková K, Urban R, Surovková J, Kurilová V. Smartphone-Based Facial Scanning as a Viable Tool for Facially Driven Orthodontics Sensors. 2022;

Yuanfang Li, Hao Tang, Ying Liu, YancongQiao, Hongqi Xia, Jianhua Zhou,

Oral wearable sensors: Health management based on the oral cavity, May2022

Turino, C.; Benítez, I.D.; Rafael-Palou, X.; Mayoral, A.; Lopera, A.; Pascual, L.; Vaca, R.; Cortijo, A.; Moncusí-Moix, A.; Dalmases,M.; et al. Management and Treatment of Patients With Obstructive Sleep Apnea Using an Intelligent Monitoring System Based onMachine Learning Aiming to Improve Continuous Positive Airway Pressure Treatment Compliance: Randomized ControlledTrial. J. Med. Internet Res. 2021, 23, e24072

Pépin, J.L.; Letesson, C.; Le-Dong, N.N.; Dedave, A.; Denison, S.; Cuthbert, V.; Martinot, J.B.; Gozal, D. Assessment of Mandibular Movement Monitoring With Machine Learning Analysis for the Diagnosis of Obstructive Sleep Apnea. JAMA Netw. Open 2020,3, e1919657.

Ravi J, Jnaneshwar P, Krishnaraj R, Ravi K. Comparison of Roll and Pitch Among Patients with Vertical and Horizontal Skeletal Patterns Using Cant-O-Meter: A New Gyroscopic Device for Measuring Occlusal Cant. Journal of Indian Orthodontic Society. 2022;56(2):189-192.

Rahman L, Kumar P R, Kalavathy N, Shetty M, Sanketh AK, Roopa M. Digital occlusal analysis of bite force distribution in partially edentulous patients before and after prosthetic rehabilitation: An in vivo study. SRM J Res Dent Sci 2021;12:204-9

Sarma TD, Mandal A, Zahir S, Kundu GK. Childhood bruxism. SRM Journal of Research in Dental Sciences. 2019 Jan 1;10(1):47.

Jansen van Vuuren, L., Jansen van Vuuren, W. A., Broadbent, J. M., Duncan, W. J., and Waddell, J. N. (2020). Development of a bite force transducer for measuring maximum voluntary bite forces between individual opposing tooth surfaces. J. Mech. Behav. Biomed. Mater. 109:103846. doi: 10.1016/j.jmbbm.2020.103846

Li, C. Luo, Q. Fu, C. Zhou, M. Ruelas, Y. Wang, J. He, Y. Wang, Y.S. Zhang, J. ZhouA transparent, wearable fluorescent mouthguard for high-sensitive visualization and accurate localization of hidden dental lesion sites Adv. Mater., 32 (21) (2020), Article e2000060

Karthikeyan V, Chander NG, Anitha KV. A salivary sensor for the management of xerostomia in edentulous patients. J Prosthet Dent. 2019 Mar;121(3):384-386. doi: 10.1016/j.prosdent.2018.07.003. Epub 2018 Dec 13. PMID: 30554820.

Lee, S.; Lee, C.; Bosio, J.A.;Melo, M.A.S. Smart Flexible 3D Sensor for Monitoring Orthodontics Forces: Prototype Design and Proof of Principle Experiment. Bioengineering 2022, 9, 570.

Gao J, Liu L, Gao P, Zheng Y, Hou W, Wang J. Intelligent Occlusion Stabilization Splint with Stress-Sensor System for Bruxism Diagnosis and Treatment. Sensors (Basel). 2019 Dec 22;20(1):89.

Bos A., Hoogstraten J., Prahl-Andersen B. Towards a comprehensive model for the study of compliance in orthodontics. Eur. J. Orthod. 2005;27:296–301.

Frilund E., Sonesson M., Magnusson A. Patient compliance with Twin Block appliance during treatment of Class II malocclusion: A randomized controlled trial on two check-up prescriptions. Eur. J. Orthod. 2022:cjac046.

Vanderveken O.M., Dieltjens M., Wouters K., De Backer W.A., Van de Heyning P.H., Braem M.J. Objective measurement of compliance during oral appliance therapy for sleep-disordered breathing.

Thorax. 2013;68:91. Dieltjens M., Verbruggen A.E., Braem M.J., Wouters K., Verbraecken J.A., De Backer W.A., Hamans E., Van de Heyning P.H., Vanderveken O.M. Determinants of Objective Compliance During Oral Appliance Therapy in Patients With Sleep-Disordered Breathing: A Prospective Clinical Trial. JAMA Otolaryngol.–Head Neck Surg. 2015;141:894–900. Inoko Y.,

Yoshimura K., Kato C., Morita O., Kohno M. Efficacy and safety of temperature data loggers in measuring compliance with the use of oral appliances. Sleep Biol. Rhythm. 2009;7:188–192.

Ackerman, Marc & McRae, Morgan & Longley, William. (2009). Microsensor technology to help monitor removable appliance wear. American journal of orthodontics and dentofacialorthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics. 135. 549-51. 10.1016/j.ajodo.2008.06.021.

Vickram, A. S., Samad, H. A., Latheef, S. K., Chakraborty, S., Dhama, K., Sridharan, T. B., ... & Gulothungan, G. (2020). Human prostasomes an extracellular vesicle–Biomarkers for male infertility and prostrate cancer: The journey from identification to current knowledge. International journal of biological macromolecules, 146, 946-958.

Pratt, M.C.; Kluemper, G.T.; Lindstrom, A.F. Patient compliance with orthodontic retainers in the post-retention phase. Am. J.Orthod. Dentofac. Orthop. 2011, 140, 196–201