International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 08 – Issue 06 || June 2023 || PP. 18-23

A Survey on IoT-Based Bite Force Measurement Techniques: From Sensors to Analytics

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Abstract: This review paper explores the impact of Internet of Things (IoT) technology in dentistry, specifically focusing on advancements in bite force measuring systems and sensors. It delves into the evolution of IoT in dental practice and examines the latest developments in bite force measurement through a comprehensive literature review. Measuring bite force is extremely important for diagnosing and treating dental issues. This research contributes to enhancing our knowledge of bite force measuring systems that are enabled by IoT technology. By incorporating IoT into dental practices, oral healthcare providers gain access to advanced tools that enable personalized treatments and ultimately improve the overall care they can provide to patients. The paper also addresses design challenges related to implanted electronic sensors, emphasizing the need to overcome these challenges for accurate measurements and the full potential of IoT in dentistry.
Keywords: IoT, bite force, force sensors, teledentistry.

1. Introduction

An IoT has brought about transformative changes in various aspects of our daily lives, including significant advancements in the healthcare industry. Leveraging IoT technologies can greatly enhance patient engagement and communication. By utilizing their smartphones or other connected devices, patients can receive timely notifications and reminders regarding dental appointments, oral hygiene practices, and personalized treatment plans. The integration IoT technology in dentistry has led to remarkable advancements, revolutionizing various aspects of dental practice. Among these advancements, the measurement of bite force has emerged as a critical element in the diagnosis and treatment of dental conditions such as temporomandibular disorders, prosthodontics, and orthodontics.

Accurate assessment of bite force holds immense significance for dental professionals as it enables informed decision-making, personalized treatment plans, and improved treatment outcomes. Various sensors and systems have been developed to capture and quantify bite forces, encompassing force-sensitive resistors, pressure mapping systems, strain gauges, and electromyography. Each approach offers distinct advantages and limitations, which will be meticulously examined in this research.

The integration of IoT technology provides dental professionals with advanced diagnostic tools and treatment planning capabilities. Using interconnected devices and data analytics empowers dental practitioners to gain valuable insights into patients' bite force profiles, leading to enhanced patient care and personalized treatment strategies.

Bite force measurement is a technique used to quantify the strength of jaw muscles during biting or chewing. It plays a crucial role in various fields, including dentistry, biomechanics, and animal physiology. By measuring bite force, dental professionals can diagnose dental conditions, evaluate oral health, assess the effectiveness of dental treatments, and gain insights into the performance and function of the chewing system. Bite force measurement devices employ specialized sensors and equipment to accurately capture and analyze the forces involved in biting. These measurements contribute to a deeper understanding of oral function and aid in the development of improved dental interventions.

This research paper aims to delve into the introduction of IoT in dentistry, specifically focusing on the advancements in bite force measuring systems and sensors. Through a thorough review of pertinent literature, this study explores the evolution of IoT technology within dental practice and investigates the latest developments in bite force measurement methodologies.

2. Literature Survey

The IoT has gained significant traction, transforming industries and everyday life. In dentistry and biomedical engineering, IoT, also known as the Internet of Dental Things (IoDT), is being explored. IoDT holds great promise for dental clinics by introducing smart capabilities to enhance patient care and treatment outcomes. With interconnected devices and systems, IoDT enables seamless data exchange, real-time monitoring, and improved diagnostics and treatments. This technology has the potential to optimize dental practice management, enhance patient experiences, and revolutionize oral healthcare delivery worldwide [1].

The Internet of Medical Things (IoMT) is a technology that involves the interconnection of medical devices and healthcare systems through the internet, enabling seamless data exchange and remote monitoring in the healthcare industry. In dentistry, the IoMT holds great potential for transforming the way dental care is delivered. IoDT encompasses the integration of dental devices, sensors, and systems with internet connectivity, allowing for real-time monitoring, data analysis, and improved patient care. This technology enables dentists to remotely monitor patients' oral health, track treatment progress, and provide personalized care interventions [2].

In home dental care is gaining popularity. This study explores the feasibility of using in-home dental treatment to improve accessibility to oral healthcare services. Software applications enable remote consultations, pre-examinations, assessments, and appointment scheduling, offering convenience for patients. A gyroscope sensor captures detailed teeth photographs, suitable for both adults and children, with optimal lighting conditions. Affordable hardware facilitates home users' engagement in dental care. Ongoing efforts to enhance identification rates and algorithm efficiency contribute to accurate diagnoses and treatment planning. Embracing in-home dental treatment allows individuals to access oral healthcare conveniently and cost-effectively in their own homes [3].

Ongoing research in dentistry focuses on developing novel sensors with exceptional qualities to enhance dental processes. This sensor stands out for its remarkable accuracy and ease of use, simplifying data collection and measurements. These advantages improve diagnostics, treatment planning, and overall dental care outcomes. By leveraging the capabilities of this sensor, dentistry professionals can achieve enhanced accuracy and efficiency, resulting in better patient experiences and outcomes. Continued advancements in sensor technology hold promising prospects for further improving dental procedures [4].

Dentistry research is shaped by five key trends: ML/AI, PM, AR/VR, RP, and telehealth care. These trends drive advancements in diagnostics, personalized treatments, education, 3D modeling, and remote care. Emphasizing individualized and holistic oral healthcare, dentistry strives for efficiency and patient-centered approaches [5].

Establishing a virtualized clinical network/database has immense potential for advancing dental research and evidence-based dentistry. This network enables efficient collaboration, knowledge sharing, and integration of clinical data and research findings. Dental practitioners contribute anonymized patient data, while researchers access the comprehensive dataset for rigorous analysis and evidence-based guidelines. The network serves as a centralized platform, promoting interdisciplinary collaboration and accelerating the translation of scientific knowledge into clinical practice. Real-time data collection enables continuous monitoring of treatment outcomes. Leveraging a virtualized clinical network/database drives innovation, improves patient care, and enhances evidence-based decision-making in dentistry [6].

Teledentistry is an innovative approach that utilizes modern telecommunications to enhance dental care delivery. It enables remote access to dental services, overcoming geographical barriers and increasing convenience. Through teledentistry, patients can receive early diagnosis, preventive care, and treatment recommendations from dental professionals through virtual consultations and digital image exchange. This approach is particularly beneficial for individuals in underserved areas. Teledentistry promotes continuity of care, ongoing monitoring, and proactive management of dental conditions. By expanding access to oral health care, teledentistry improves patient outcomes and contributes to overall oral health promotion [7].

A comparative investigation compared the impact of hard and soft materials on bite force measurement. Results showed that using a soft surface yielded higher bite force measurements. The study used a Digital GM10 bite force meter, which provided reliable and accurate measurements. Soft bite surfaces demonstrated advantages in assessing bite force due to their reliability and precision. However, a drawback was noted with the plastic-covered biting element, which could impede optimal functioning of the oral sensor motor and pose challenges in determining the optimum biting force. Consideration should be given to potential limitations of materials used in bite force evaluations [8].

Veena Jain et. al [9] explored the correlation between maximum bite force in the first molar region and moderate-to-severe attrition. A piezoelectric transducer-based instrument was used to assess bite force, offering advantages such as insensitivity to electromagnetic fields, radiation, and high-temperature stability. Results showed that participants with moderate-to-severe attrition had significantly lower maximum biting forces. However, further investigation involving various sub-groups indicated that bite force alone is not a definitive causal factor for tooth wear. More research is needed to gain a better understanding of the relationship between maximum bite force and tooth attrition.

A cost-effective bite force measuring tool has been developed using the Flexiforce A201 sensor with a unique housing design. This tool is suitable for both clinical and laboratory settings to evaluate mechanical properties. The housing layers enhance sensor sensitivity, leading to more accurate bite force measurements. However, the tool's sensitivity increases non-linearly, which may introduce slight inaccuracies. Nevertheless, this budget-friendly tool with its innovative design shows promises for assessing bite force in various applications, offering improved sensitivity without compromising affordability [10].

A low-cost biting force measuring device has been developed using a low-cost alloy steel load cell. This device considers individual morphology and precise gadget placement in the mouth for accurate bite force estimation. Its advantages include open-source accessibility, affordability, portability, and user-friendly operation, providing reliable measurements. Future innovations may involve integrating cost-effective electromyography (EMG) equipment to enhance device capabilities. In summary, this low-cost device offers a practical solution for assessing bite force in scientific research and clinical applications [11].

L. Jansen van Vuuren et. al [12] assessed maximum voluntary biting forces using a Strain Gauge Resistance sensor to measure opposing tooth surfaces. The method offers advantages such as compact size, user-friendly operation, and high accuracy. The sensor enables precise and reliable measurements of biting forces, providing valuable insights for research and clinical applications. Overall, this approach offers a convenient and efficient method for studying bite forces.

A novel biting force-measuring device has been developed using an FSR-402 sensor, focusing on cost reduction. The device includes a calibration instrument to ensure measurement accuracy and reliability. Its key advantages include affordability, user-friendliness, good linearity, and repeatability. Ongoing improvements aim to reduce errors by decreasing the sensor sheath size. This unique device provides a cost-effective solution with simplicity, accuracy, and repeatability in bite force assessments [13].

Claudius Steffen et. al [14] aimed to evaluate a new bite force measurement device that utilizes a capacity-type pressure-mapping sensor. The equipment offers several advantages, including high reliability and feasibility, ensuring consistent and accurate measurements. Its portability allows for convenient use in clinical and research settings. This advanced technology provides detailed information about force distribution during biting, enabling tailored reconstructive treatments. By improving the reliability and feasibility of assessing bite forces, this device has the potential to optimize patient outcomes and contribute to personalized treatment approaches [14].

A. Shimada et. al [15] examined the relationship between biting force control, electromyographic (EMG) activity, and jaw movements during mastication in humans. It utilizes a newly developed intraoral bite force sensor to capture real-time data, making it highly feasible. The findings provide fresh insights into the dynamics of human chewing, highlighting the correlation between biting force control, EMG activity, and jaw movements. This knowledge has significant clinical relevance, offering insights into normal masticatory function and potential applications in the diagnosis and treatment planning of orofacial conditions. The study's practical implications benefit both researchers and clinicians, enhancing our understanding of the complexities involved in human chewing.

A new bilateral biting force sensor has been developed, capable of measuring forces up to 1000 N. It provides insights into force symmetry and is valuable for assessing bite force in individuals with temporomandibular problems. The sensor's high accuracy and unique design make it a valuable tool for clinicians and researchers in managing temporomandibular disorders [16].

Jarred Fastier Wooller et. al [17], focused on the design and implementation of minimally invasive sensors for measuring maximal voluntary bite force. The sensors are fabricated in-house using laser-cutting acrylic devices. With a measurable range of 0-700 N, these sensors offer several advantages. They are cost-effective, utilizing affordable materials, while maintaining excellent linearity and reproducibility in their measurements. These characteristics make the sensors highly practical and reliable for assessing bite force in various dental and research applications.

Nickolay Apostolov et. al [18] aimed to determine the maximum biting force (MBF) in individuals with normal dentition using a specialized force-measuring tool called a gnathodynamometer. The findings showed that male participants had a higher MBF than females, indicating gender-related variations in biting force. These results contribute to our understanding of normal dentition and highlight the significance of considering gender-related factors in assessing biting forces.

A portable and user-friendly electric circuit has been developed, integrating the FlexiForce sensor (A401) to measure masticatory forces accurately. This circuit offers several benefits, including hygiene maintenance with its replaceable exterior sensor and convenient data collection through digital outlets. It can determine both the highest and lowest masticatory forces, providing a comprehensive understanding of the masticatory load. This innovative solution enables reliable and repeatable measurements for further research and analysis [19].

Santosh R. Patil et. al [20] assessed the reliability of determining maximal biting force (MBF) through inter- and intra-examiner evaluations. The MBF was measured using both a biting force sensor and an occlusal force meter, capturing the maximum bite force alternately. Statistical analysis techniques, including the kappa statistic and Pearson's correlation coefficient, were utilized to evaluate measurement reliability. The approach demonstrated advantageous features such as accuracy, linearity, and repeatability, ensuring consistent and dependable MBF assessment. The research offers valuable insights into the reliability of measuring MBF, providing a basis for further investigations and potential guidance for clinical practices related to bite force assessment.

A novel force sensor has been developed to accurately measure axial force and bending moment. By incorporating three sensor cells in each of the two planes, the sensor effectively detects bending direction. The obtained results exhibited desirable characteristics such as nonlinearity, repeatability, and accuracy. This design offers the advantage of comprehensively sensing both axial force and bending moment, enabling precise measurements for various applications. The sensor's utilization can contribute to mitigating surgical errors, preventing fatigue-related issues, and ensuring proper force distribution and load management. Overall, this force sensor design provides a reliable and versatile solution, offering enhanced safety, accuracy, and performance across different fields [21].

The bite force recorder surpasses existing devices in multiple aspects, establishing itself as a superior tool for measuring bite force. It excels in sensitivity, accuracy, and reproducibility, ensuring reliable measurements. Its compact design, battery operation, and hygienic disposable covers enhance its practicality and user-friendliness. The device's ability to generate precise readings in a simplified manner makes it suitable for both field studies and clinical settings. Overall, this cutting-edge bite force recorder offers significant advantages, providing clinicians and researchers with an efficient and reliable instrument to assess and monitor bite force accurately [22].

A study was carried out to examine the maximal biting forces among individuals with and without dental implants, utilizing a digital bite force transducer (GM10). The research aimed to evaluate the influence of factors such as age, sleep/awake status, and sex bruxism on these forces. However, to ensure conclusive and reliable results, it is imperative to conduct a well-designed study with a larger sample size. This would provide more robust evidence and a clearer understanding of the relationship between biting forces and the aforementioned factors.

Adam Yasunaga et. al [24] focused on molecular force sensors, studying their tunability, signal-to-noise ratio, and impact on biological systems. These sensors detect and measure molecular forces, offering insights into biological processes. Understanding their tunability determines sensitivity and range. Evaluating signal-to-noise ratio ensures accurate measurements. Considering their impact on biological systems is crucial. Further research on sensor spatial densities can enhance sensitivity. This advances molecular force sensor development, deepening our understanding of cellular and molecular mechanics.

A ground-breaking wireless system is introduced for identifying moisture seeps, offering convenience and flexibility. However, thorough investigation of the surrounding environment and potential obstacles is required for optimizing the distribution of DC power within the system. Efforts are being made to enhance color determination accuracy while streamlining processes for improved productivity. These advancements aim to provide accurate and efficient means of detecting and addressing moisture seepage issues, benefiting industries and applications involving moisture control and management [25].

3. Challenges

The widespread adoption of IoT faces several significant challenges that need to be addressed for its successful implementation. One major hurdle is ensuring the security of IoT devices to protect sensitive data from unauthorized access or breaches. Another challenge is achieving seamless interoperability among devices from different manufacturers, allowing them to work together efficiently. Additionally, handling the exponential growth in the number of devices and the massive volume of data they generate poses a significant challenge.

Efficient power management is crucial, particularly for IoT devices that rely on batteries. Optimizing power usage to prolong battery life and ensure continuous operation is essential. Furthermore, the management and analysis of the vast amount of data generated by IoT devices present a considerable undertaking, requiring effective data handling and meaningful insights extraction.

In the context of bite force measurement devices, there are specific challenges that need to be addressed. Ensuring accurate and consistent measurements is a primary concern, requiring precise calibration and validation processes. Determining the optimal sensor placement and creating comfortable devices can also prove challenging, as it involves finding a balance between usability and accurate data acquisition. Establishing common standards and best practices across the industry would greatly facilitate the development and adoption of bite force measurement devices.

Real-time monitoring is critical for certain applications, necessitating reliable and prompt data acquisition. Having a robust infrastructure and communication framework is essential to enable rapid and dependable data transmission. Finally, it is crucial to design bite force measurement devices with user-friendliness in mind, catering to individuals who may have limited experience using such devices. Simplifying the user interface and providing clear instructions and guidance can enhance usability and accessibility.

By addressing these challenges and investing in research and development, we can enhance the effectiveness and widespread adoption of IoT and bite force measurement devices, unlocking their full potential in various domains.

4. Conclusion

In conclusion, the integration of IoT technology in bite force measurement has significantly advanced in the field of dentistry. By leveraging IoT-enabled systems and sensors, dental professionals can obtain more accurate and precise measurements of bite force, leading to improved diagnostic capabilities and personalized treatment plans. The utilization of IoT in bite force measurement offers enhanced patient engagement and communication through timely alerts and reminders. However, further research and development are needed to address design challenges and optimize the implementation of implanted electronic sensors for seamless integration within the dental structure. Overall, the combination of IoT and bite force measurement holds great potential for enhancing dental care, facilitating better treatment outcomes, and improving the overall patient experience.

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