Application and Development of Digital Technology in Dental Restoration

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Abstract: Oral restoration is one of the core tasks in the field of dentistry, and the application and development of digital technology are rapidly changing the methods and quality of oral restoration. This paper delves into the significance and impact of digital technology in oral restoration and provides a detailed discussion of its current applications and developments, with the hope of driving the application of digital technology in the field of oral restoration.

1. Introduction

Oral health plays a vital role in human life, encompassing various aspects from food digestion to social interactions, and its impact on overall health. However, oral issues and dental damage are common, requiring timely restoration and treatment. Oral restoration is a critical branch of dentistry that covers a wide range of treatments, including tooth restoration, tooth replacement, periodontal disease management, and cosmetic dentistry. The importance of oral restoration lies not only in the aesthetic and functional restoration but also in its profound impact on a patient's overall quality of life and health. Inadequate oral restoration may lead to chewing difficulties, speech problems, diminished self-esteem, emotional stress, and even negative consequences on a patient's systemic health. Therefore, oral restoration is not merely a cosmetic concern but a healthcare service that significantly influences a patient's comprehensive well-being. With the aging population and improved standards of living, the demand for oral restoration is continually increasing. Additionally, scientific and technological advancements in the field of oral medicine are driving the evolution of oral restoration. In this context, the application of digital technology in oral medicine becomes especially important.

Digital technology has already made significant inroads in various fields, including healthcare. In the field of oral medicine, digital technologies such as digital scanning and CAD/CAM (Computer-Aided Design/Computer-Aided Manufacturing) systems are beginning to be widely adopted. The introduction of these technologies marks a revolution in the field of oral restoration. They not only offer more precise and predictable treatment approaches but also change the way patients interact with healthcare providers and the working methods of oral healthcare professionals. Digital scanning technology can non-invasively and accurately obtain three-dimensional images of oral structures. This enables oral healthcare providers to diagnose issues more accurately, plan treatments, and develop personalized restoration plans for patients. Compared to traditional impression methods, digital scanning technology is not only more comfortable but also reduces

errors and treatment time. CAD/CAM technology, on the other hand, allows oral healthcare providers to create restorations such as crowns, bridges, and dentures using computer-assisted design and manufacturing. The benefits of this approach include highly personalized treatments, precision, and speed. Patients can receive restorations more quickly, and these items fit their oral structures more accurately. Digital technology has also transformed the interaction between patients and oral healthcare providers. Patients can gain a clearer understanding of their oral issues, participate in treatment planning through visualization, and enhance their satisfaction and treatment cooperation.

2. The Evolution of Digital Technology in Oral Medicine

The evolution of digital technology in oral medicine is a remarkable process that has completely transformed the practice and treatment outcomes of oral medicine.

2.1 Introduction of Early Digital Technology

The early introduction of digital technology in oral medicine primarily focused on the field of imaging. Traditional radiographic images, such as X-ray films, had some limitations, including high radiation doses and two-dimensionality of images. The introduction of digital radiography technology (such as digital X-rays and Cone Beam Computed Tomography, CBCT) marked a revolution in this field. Digital radiography technology captures images using digital sensors, providing higher-quality three-dimensional images of oral structures, reducing radiation doses, and allowing healthcare providers to make better diagnoses and treatment plans.[1]

2.2 Electronic Health Records (EHR)

The emergence of Electronic Health Records (EHR) allows healthcare providers to better manage clinical data. Compared to traditional paper records, EHRs enable oral healthcare providers to more easily record patients' medical histories, clinical observations, diagnoses, and treatment plans. This digital medical record enhances information accessibility, searchability, and shareability, making it easier for healthcare providers to make clinical decisions and ensure the proper management of patients' health information.

2.3 Three-Dimensional Digital Scanning Technology

The rise of three-dimensional digital scanning technology has had a profound impact on oral medicine. This technology utilizes laser or grating projection to create precise three-dimensional models of oral structures. Compared to traditional molding, digital scanning technology offers greater comfort, eliminating the discomfort associated with traditional impressions. Additionally, digital scanning provides more accurate data, which can be used to create high-quality restorations such as crowns, bridges, dentures, and reduces the number of adjustments needed during the restoration process.

2.4 Application of CAD/CAM Technology

The introduction of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology allows oral healthcare providers to design and manufacture oral restorations on a digital platform. CAD/CAM systems obtain precise data of oral structures through digital scanning and then use computer algorithms for the design and manufacturing of restorations. This approach

provides highly personalized restorations that better suit the individual characteristics of patients' oral cavities. Furthermore, CAD/CAM technology enhances precision in manufacturing, reduces production time, and expedites the treatment process.

2.5 The Emergence of 3D Printing Technology

One of the latest advancements in digital technology is the application of 3D printing technology in oral medicine. Through 3D printing, oral healthcare providers can rapidly manufacture complex oral restorations, such as crowns, bridges, and dentures. This technology not only saves time but also enhances precision and personalization in manufacturing. 3D printing technology is becoming a prominent field in digital oral restoration, providing patients with improved treatment experiences and outcomes.

The evolution of digital technology in oral medicine has made significant progress, from enhancing diagnostics to improving treatment outcomes. These technologies continue to innovate and improve, providing higher precision, personalized treatments, and patient satisfaction in oral medicine. They also offer limitless possibilities for the future of oral medicine.

3. Application of Digital Scanning Technology in Oral Restoration

Digital scanning technology is a method of obtaining three-dimensional data of an object's surface through optical or laser scanning. In the field of dentistry, digital scanning technology is widely applied for precise measurements of oral structures and the creation of digital models.

Digital scanning technology typically employs optical or laser scanners that emit light beams (either lines or laser beams) and record the reflection of these beams to perform the scanning. These beams move rapidly through the scanning area while measuring the time and angle of beam reflection. During the digital scanning process, the instrument utilizes the principle of triangulation to calculate the three-dimensional coordinates of individual points on the object's surface. This principle is based on the relationships between the incident angle of the light beam, the exit angle, and the baseline length to determine the position of points. Multiple measurements are taken from different angles and positions to create a complete three-dimensional model. The scanner records the coordinate data for each point, which is then compiled by a computer into a high-resolution three-dimensional model.[2]

Before digital scanning begins, preparation of the patient's oral cavity is necessary to ensure dryness and clear visibility of oral structures. The healthcare provider uses the digital scanner, holding it within the patient's oral cavity to initiate the scanning process. The scanner emits light beams and records their reflections to obtain three-dimensional data of the oral structures. The scanner transmits the collected data to a computer, where software processes the data into an accurate three-dimensional model. Healthcare providers can use specific software tools to edit the three-dimensional model, mark specific areas, or perform other necessary operations. The generated three-dimensional model can be utilized for various dental applications, including diagnosis, treatment planning, restoration design, and manufacturing.

Digital scanning is employed for recording the precise internal structures of the oral cavity for diagnostic and treatment planning purposes. Healthcare providers can view the three-dimensional model on a computer screen, allowing for a more accurate assessment of the health of teeth and any issues. Digital scanning can be used to detect caries or changes in enamel mineralization, aiding in the early detection and treatment of oral diseases. Scanning technology is utilized for analyzing a patient's bite relationship, assisting in the diagnosis of temporomandibular joint (TMJ) issues and facial pain.

Digital scanning technology accurately measures the shape and size of a patient's oral structures,

ensuring a perfect fit of restorations with the patient's teeth and gums. Three-dimensional models created based on digital scanning are used for personalized design of restorations such as crowns, bridges, dentures, and more. Healthcare providers can adjust the design on a computer to meet the specific needs of the patient. Digital scanning technology allows the digital model of the restoration to be used directly in Computer-Aided Manufacturing (CAD/CAM), expediting the manufacturing process of restorations. Due to precise measurements and personalized design, digital scanning technology can reduce the number of adjustments needed for restorations, enhancing treatment outcomes and patient satisfaction.

4. Application of CAD/CAM Technology in Oral Restoration

4.1 Principles and Workflow of CAD/CAM Technology

CAD/CAM stands for Computer-Aided Design and Computer-Aided Manufacturing, representing a digital technology used for designing and manufacturing various oral restorations such as crowns, bridges, and dentures. Below are the principles and workflow of CAD/CAM technology:

In the design phase, healthcare providers use CAD software to create a digital model of the restoration. This can be achieved through two methods: scanning and manual design. Three-dimensional data of oral structures are captured within the oral cavity using digital scanning technology, and then the model of the restoration is edited and designed on a computer. Alternatively, healthcare providers can manually design the model of the restoration, which is then digitized using CAD software. CAD software offers various tools that allow healthcare providers to make precise modifications and designs on the model, ensuring that the restoration meets the patient's oral needs.

In the manufacturing phase, the digital model is transmitted to CAM software, which guides the operation of manufacturing equipment. Manufacturing equipment such as CNC milling machines or 3D printers produce the restoration based on the design specifications within the digital model. Various materials, including ceramics, resins, metals, and others, can be used for manufacturing. The manufacturing equipment precisely carves, cuts, or prints the final shape of the restoration according to the exact guidance provided within the digital model.[3]

The patient's oral cavity is either scanned to obtain three-dimensional data or traditional methods, such as molds, are used to create a model of the oral structures. The three-dimensional scan data or data from traditional molds is transferred to CAD software. Healthcare providers use CAD software to create or edit the digital model of the restoration, ensuring it fits the patient's teeth and oral cavity.

CAD software generates the numerical control (NC) code for manufacturing. NC equipment, such as CNC milling machines or 3D printers, produces the restoration based on the NC code.

The manufactured restoration is then installed in the patient's oral cavity and undergoes final adjustments and fixation.

4.2 Application of CAD/CAM Technology in the Production of Oral Restorations

CAD/CAM technology finds extensive application in the field of oral restoration. It is used for the fabrication of dental crowns (single-tooth coverings) and bridges (restorations used to replace missing teeth). Healthcare providers can create precise restorations tailored to the patient's oral structures, ensuring a perfect match with the surrounding teeth. CAD/CAM technology is also highly valuable in the fabrication of full-mouth dentures (complete tooth replacements) and partial dentures (partial tooth replacements). These dentures can be customized in design to restore a

patient's chewing function and aesthetics. CAD/CAM technology is employed for the production of implant-supported restorations, which are restorations that integrate with dental implants to replace missing teeth.

4.3 Emphasizing the Advantages of CAD/CAM Technology

CAD/CAM technology offers several advantages in oral restoration. It enables healthcare providers to design highly precise and personalized treatment plans based on a patient's oral structures and needs, ensuring restorations that perfectly match the patient's oral cavity. The digital design and manufacturing process reduce human errors, enhancing the accuracy of restorations and minimizing the need for adjustments. CAD/CAM technology significantly reduces manufacturing time, enabling patients to receive restorations more quickly and reducing treatment wait times. CAD/CAM technology allows oral healthcare providers to record a patient's digital model in electronic health records, facilitating better management of a patient's treatment history and progress.

5. Impact of Digital Technology on Oral Restoration

Digital technology has had a profound impact on oral restoration, including improvements in treatment outcomes, patient satisfaction, and healthcare provider workflows.

5.1 Improvement in Treatment Outcomes

Digital technology enables oral healthcare providers to create highly accurate and personalized treatment plans. For example, digital scanning and CAD/CAM technology ensure that oral restorations fit perfectly with a patient's oral structures, resulting in longer-lasting treatment outcomes. Digital imaging allows healthcare providers to detect dental caries and other oral issues earlier, enabling early intervention to prevent worsening conditions and improve treatment outcomes.

5.2 Increase in Patient Satisfaction

Digital technology is typically more comfortable for patients compared to traditional methods, reducing discomfort such as gagging or pain during procedures like molding. This enhances the overall patient experience and increases satisfaction. Digital technology allows patients to have a clearer understanding of their oral issues and participate in treatment planning through visual aids. This increases patient understanding and cooperation with treatment.[4]

5.3 Improvement in Healthcare Provider Workflow

Digital technology provides more accurate diagnostic and treatment planning tools, enabling healthcare providers to better understand a patient's condition and improving workflow efficiency. Electronic Health Records (EHRs) allow oral healthcare providers to easily record and manage patient data, including diagnoses, treatment plans, and progress.

6. Interaction between Patients and Digital Technology

6.1 Patient Attitudes and Expectations Regarding Digital Technology

Patients generally have a positive attitude towards the application of digital technology in oral

healthcare because it can enhance treatment effectiveness, comfort, and personalization.

Patients expect digital technology to reduce discomfort during treatment processes, such as the use of digital scanning instead of traditional molding. They hope that digital technology can shorten treatment duration and reduce the need for multiple visits. Patients expect digital technology to provide personalized treatment plans to ensure that restorations match their oral structures and needs. They wish to see digital models to have a clearer understanding of the treatment process and expected outcomes. Patients desire the ability to participate in treatment decisions, including material and design choices for restorations. Patients expect digital technology to be used for their education, helping them better understand oral issues and treatment options.

6.2 How Digital Technology Enhances Patient-Provider Communication and Education

Digital technology in oral healthcare enhances communication and education between patients and healthcare providers, increasing treatment transparency and patient satisfaction. Healthcare providers can use digital scanning and X-ray images to show patients their oral issues. These visual tools enable patients to better comprehend their condition and make informed decisions about treatment. Digital technology allows healthcare providers to simulate treatment processes on a computer, showing expected outcomes. Patients can see the differences before and after treatment on the screen, aiding their involvement in treatment planning. Healthcare providers can share digital models with patients, allowing them to view and rotate oral structures on a computer. This interactive involvement enhances patients' understanding and engagement in treatment. Some oral healthcare providers use online platforms or applications to allow patients access to their electronic health records and educational materials at any time [5]. This convenience helps patients better manage and track their oral health. Digital technology makes the shared decision-making process easier, enabling patients to discuss different treatment options, material choices, and cost estimates with their providers. Some digital systems allow patients to electronically sign treatment consent forms, increasing patient proactiveness in treatment planning.

7. Conclusion

In conclusion, despite facing challenges, the continuous development of digital technology has brought significant potential to the field of oral restoration, offering patients improved oral health and aesthetics. The future of this field will continue to benefit from the innovation and application of digital technology.

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