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Digital Dentistry: Revolutionizing Dentistry with CAD/CAM Technology

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Abstract

CAD/CAM systems revolutionize dentistry by digitally designing prosthetic structures on a computer and then fabricating them with milling machines. Over the past few decades, this technology has significantly advanced dental practices, aiming to enhance the efficiency of prosthetic work production. Among the CAD/CAM systems used in dentistry, notable ones include Zirkonzahn, CEREC, Procera, Lava, and Everest.

Keywords: CAD/CAM Technology; CAD/CAM System Types; CEREC; Metal Free; Zicronium

Introduction

Over time, prosthodontics and implantology have undergone notable transformations due to advancements in various restorative materials. Meeting the aesthetic expectations of patients has become increasingly challenging, given the plethora of techniques and materials available for prosthetic rehabilitation [1]. Ceramic restorations play a crucial role in ensuring long-term clinical success not only because of their mechanical properties, aesthetic appeal, and biocompatibility but also due to their ability to precisely adapt to the dental structure. This aspect is considered pivotal in assessing the effectiveness of such rehabilitations [2,3]. Mormann WH [4] observe significant progress in CAD/CAM technology over the past three decades, encompassing optical, contact, and laser digitization of dental preparations, virtual design software, a variety of materials (including alumina, zirconia, and titanium), and the fabrication of restorations.

CAD/CAM technology has revolutionized dentistry, particularly in responding to the demand for fixed restorations among patients. The term CAD/CAM denotes the process of designing a prosthetic structure on a computer (Computer-Aided Design) and then manufacturing it using a milling machine (Computer-Aided Manufacturing), a practice introduced to dentistry in the late 1970s [5]. The CAD/CAM system typically comprises three main components: a digital scanner for virtual scanning of preparations, impressions, or models; CAD software for designing the future restoration digitally; and a CAM unit for cutting ceramics and producing the restoration or infrastructure. The precision of indirect restorations' adaptation can be influenced by any or all of these stages [6].

History

The term CAD/CAM, derived from Computer-Aided Design and Computer-Aided Manufacturing [7], originated in the

aerospace and automotive industries before being introduced to dentistry by Bruce Altschuler in the USA, François Duret in France, and Werner Mormann and Marco Brandestini in Switzerland between the late 1970s and early 1980s. According to Moura, et al. the adoption of this technology in dentistry aimed to streamline and standardize fabrication processes while reducing production costs [8]. These systems offer several advantages, including enhanced reproducibility and dimensional accuracy, shorter fabrication times, the ability to utilize more resilient ceramic systems, and the production of entirely ceramic restorations. Consequently, CAD/CAM technology has become an indispensable tool in prosthesis construction.

The first commercially available system was the Cerec system, developed by Mormann, et al. Initially, only laboratory scanners were accessible, with 3D CAD images sent to processing centers abroad for milling. However, nowadays, clinics and laboratories can have their own milling equipment, streamlining the fabrication process [9]. Note that in 1984, Duret introduced the Duret System for crafting single crowns, which involved optical impression-taking, functional crown design, and controlled milling. Although offering manual independence, Duret's system was complex and costly.

Initially, the marginal adaptation of CAD/CAM restorations faced criticism due to inferior fidelity and precision compared to traditional methods. However, with technological advancements, this perception has changed, and CAD/CAM systems are now capable of achieving excellent marginal integrity [10]. Recent years have witnessed significant progress in CAD/CAM technology, including improvements in reading dental preparations, virtual design software, materials, and prosthetic restoration machining. These advancements have also propelled the development of dental materials, with ceramics becoming increasingly aesthetic, biocompatible, and mechanically robust [11].

CAD/CAM Systems

CAD/CAM technology has predominantly been utilized in dentistry for producing fixed prosthetic restorations like crowns, bridges, and veneers. However, image digitization for serial fabrication of prostheses has come with a higher cost to patients, which stands as a major drawback [12]. The term CAD/CAM, originating from Computer-Aided Design/Computer-Aided Manufacturing, embodies a next-generation three-dimensional system enabling the fabrication of prostheses. This technology, initially developed for streamlining and standardizing manufacturing processes, has found applications not only in serial production but also in surgical enhancement and general restorations through computer-assisted design and fabrication [13].

The primary objective behind adopting CAD/CAM technology is to simplify, automate, and ensure quality levels with micrometric adaptations of dental prostheses [14]. This process, stemming from the development of software and hardware, involves digitizing dental models or arches, turning them into digital files through scanning procedures. High-tech CAD/CAM systems, based on three fundamental components—dental preparation reading system (scanning), prosthetic restoration design software (CAD), and prosthetic structure milling system (CAM or milling)—have been developed by various companies [15].

CAD/CAM systems, categorized into open or closed systems based on CAD file availability, offer advantages and challenges. While open systems provide flexibility in choosing CAM systems, closed systems offer an integrated production setup. These systems can be clinic-based or laboratory-based, with Cerec being a notable example offering both modalities [16].

In terms of fabrication methods, extraoral approaches are generally preferred despite some drawbacks, such as time consumption and the need for dental preparation impressions, which may introduce errors. Intraoral digitization, though used, may not provide precise images of spatial relationships, particularly in complex prosthetic rehabilitations [17].

The CAD system, whether intraoral or laboratory-based, involves scanning dental structures and using software to design prosthetic elements with accuracy and precision. This process facilitates the creation of various restorations, including full crowns, veneers, bridges, and more [18].

Indications for CAD/CAM systems include metal-free rehabilitations, orthodontic analysis, oral surgery planning, and guided implant surgeries. These systems offer flexibility in working with different materials like ceramics, titanium, and resins, depending on the desired outcome [19].

Overall, CAD/CAM technology has transformed dental practices, offering streamlined workflows, enhanced precision, and expanded treatment options, particularly in the field of prosthodontics and oral surgery [20].

Ceramic Materials

CAD/CAM technology facilitates the creation of fixed restorations using pre-fabricated ceramic blocks made from various materials, including leucite-reinforced glass ceramics, glass-infiltrated alumina, densely sintered alumina, Y-TZP Zirconia (Yttrium-tetragonal zirconia polycrystal) with sintering (partial or full), titanium, precious alloys, non-precious alloys, and reinforced acrylic.

Zirconia, noted by Tenório stands out among other ceramic

materials due to its exceptional mechanical properties, primarily attributed to its transformation toughening mechanism. As highlighted by Correiazirconia is regarded as the most resilient material available for dental applications.

In recent years, lithium disilicate ceramics have emerged for CAD/CAM systems and gained popularity. This material, as noted by Rodrigues possesses relatively high mechanical strength and optical properties, allowing for complete restoration without the need for additional coating.

Main Features of CAD/CAM Systems Available in the Market

Zirkonzahn

Enrico Steger, the innovator behind Zirkonzahn, emphasizes the concept of bringing ideas to life with one's own hands, reflecting the company's commitment to innovation and craftsmanship. Zirkonzahn offers various software modules for restoration planning, providing comprehensive solutions for dental professionals [21].

Until 2003, Zirkonzahn's system was the sole technology capable of milling 14-tooth bridges, leveraging a powerful milling machine with a 1500W motor and weighing 350kg. This system features proven simultaneous 5+1 axis milling technology, enhancing precision and efficiency. With the ability to virtually position the workpiece within the block, Zirkonzahn's system facilitates the creation of inlays, onlays, veneers, screw-retained bridges, and bars from a wide range of materials [22].

One of the key advantages of Zirkonzahn's system is its fully automatic optical light scanner, equipped with two high-resolution cameras, enabling precise detection of preparation margins and efficient modeling and milling processes. The CAD software, Zirkonzahn Archive, facilitates project creation, management, and documentation, enhancing workflow efficiency and organization.

Zirkonzahn offers a range of CAM models, including the M4, M3, M1 Soft, M5 Heavy, and M6 Wet Heavy milling machines, each designed to meet specific needs and preferences. These machines support milling of various materials, such as zirconia, resin, wax, metal, and ceramics, catering to diverse clinical requirements.

CEREC System

In contrast, the CEREC system by Sirona Connect offers single-session treatment options with its automatic milling process, allowing for efficient production of ceramic restorations. The system boasts high precision in milling, with a marginal adaptation evaluation similar to other systems. The infrastructure of the CEREC system comprises enamel-like feldspar and glass ceramics, lithium disilicate, and high-performance polymers, ensuring biocompatibility and durability.

Procera System

Nobel Biocare's Procera system has gained significant traction in the dental industry, producing over 5 million prosthetic units to date. This CAD/CAM system utilizes contact scanning technology and offers infrastructures made of densely sintered aluminum oxide and zirconium. The Procera system's mechanical characteristics, including high resistance, make it a preferred choice among dental professionals. With specific data processing and advanced software features, the Procera system enables precise delineation of preparation margins and customization of restoration parameters.

Overall, these CAD/CAM systems revolutionize dental practices, offering advanced technology, precise restoration fabrication, and streamlined workflows to meet the evolving needs of dental professionals and patients alike.

Lava System

According to Correia the Lava system facilitates the production of ceramic crowns and bridges for both anterior and posterior regions. Optical laser imaging captures images that are then transmitted to a computer. The system's assisted design program automatically determines finishing lines and suggests pontics. To account for ceramic shrinkage during sintering, the infrastructures are designed 20% larger. Pre-sintered zirconia blocks, which can be pre-colored before final sintering, are utilized, ensuring high aesthetic levels. The Lava system includes a special high-temperature furnace for completing the sintering process. With high flexural strength, reaching up to 1400 Mpa, it offers durable restorations.

Lava system is suitable for anterior and posterior single crowns, as well as up to four-unit fixed prostheses. In a 3-year study, no fractures occurred in either anterior or posterior single crowns. Additionally, this technology provides the option to eliminate the molding stage, streamlining the process.

The Lava Scan ST Dental System by 3M ESPE is an indirect system primarily used in laboratories. It employs conventional impressions to mold the preparation traditionally, followed by digitization using a scanner. However, the Lava C.O.S system utilizes direct CAD, allowing for digitization of the preparation directly in the mouth without the need for molding procedures.

Everest System

The Everest system utilizes optical reading through a CCD camera and CAD software for restoration design, followed by milling with five-axis cutting movements. Notably, the Everest system introduces support through acrylic resin, offering flexibility in drill movement around the restoration. While this feature provides advantages such as single-session treatments and enhanced aesthetics, it also slows down the system due to manual intervention required during milling.

When evaluating CAD/CAM systems, one must consider the accuracy of the restorations produced, with internal and marginal fit within clinically acceptable parameters, typically less than 100 microns. While CAD/CAM technology offers numerous benefits, including high-quality restorations and material options, challenges such as the need for adaptation in work dynamics, clinician confidence, and equipment costs persist.

Despite advancements, the success of CAD/CAM systems in dentistry depends on several factors, including software and hardware limitations. Continued innovation and refinement are necessary to address these challenges and maximize the potential of CAD/CAM technology in prosthetic dentistry.

Discussion

The increasing emphasis on aesthetics in our society has driven industries to develop new products and technologies that balance aesthetic quality with durability. The advent of CAD/CAM technology in dentistry has revolutionized the parameters of prosthesis quality, allowing for faster and more precise production of dental restorations.

In the early days of CAD/CAM technology, only laboratory scanners were available, and the digitized images were sent abroad for processing and milling. However, now clinics and laboratories can have their own milling equipment, streamlining the process. CAD/CAM systems typically involve four stages: molding of arches and making gypsum models, scanning of models to generate a virtual working model, virtual construction or design of the prosthesis using specialized software, and finally, milling of the designed prosthesis.

One significant advantage of CAD/CAM systems is the ability to modify restorations digitally, even in the presence of large marginal discrepancies, offering flexibility and precision. Patients benefit from reduced treatment time and increased durability of restorations. However, drawbacks include the high cost of equipment and limitations in color, adaptation, and sculpture of restorations.

Zirconia is a commonly used material in CAD/CAM systems due to its aesthetic and mechanical properties. Despite variations in adaptation values influenced by factors such as scanning and milling systems, zirconia remains promising for various dental applications.

Intraoral scanners have been shown to offer superior marginal adaptation compared to traditional methods, with the CEREC AC Bluecam scanner exhibiting the shortest scanning time. Studies comparing CAD/CAM systems such as Lava and Procera have found no significant differences in fracture resistance.

Challenges in CAD/CAM systems include the high cost of equipment, the need for training and acceptance among dental surgeons and technicians, and the aesthetic issue, which may require additional characterization. However, the Everest system has demonstrated excellent aesthetic results using zirconia.

While CAD/CAM systems produce restorations with acceptable marginal adaptation, the final step of cementation is crucial for clinical success. Surface treatment of zirconia, such as sandblasting, improves bond strength between the resin cement and the restoration.

In conclusion, CAD/CAM systems have transformed dental prosthetics, offering benefits such as precision, efficiency, and durability. Despite challenges, ongoing advancements in technology and materials continue to enhance the capabilities of CAD/CAM systems in dentistry.

Conclusion

Indeed, contemporary dentistry places greater emphasis on meeting higher quality standards, particularly in terms of aesthetics and functionality. The evolution of CAD/CAM technology has been instrumental in achieving these standards, offering dental surgeons and technicians advanced tools for producing high-quality restorations. CAD/CAM systems have witnessed significant advancements since their introduction, making them increasingly popular among dental professionals. These systems are capable of delivering restorations with superior strength, precise marginal adaptation, pleasing aesthetics, and promoting soft tissue health. One of the notable advantages of CAD/CAM systems is their ability to streamline the fabrication process, reducing turnaround times for restorations. Additionally, these systems allow for the utilization of new ceramic materials that offer improved resistance, further enhancing the longevity and performance of dental restorations.

However, while CAD/CAM technology offers numerous benefits, it's important to conduct further studies to comprehensively evaluate the advantages and disadvantages of each system. This ongoing research will contribute to refining and optimizing CAD/CAM systems, ensuring they continue to meet the evolving needs and expectations of modern dentistry.

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