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REVIEW ARTICLE

Dental CAD/CAM: a brief review

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ABSTRACT

Computer-aided design and computer-aided manufacturing (CAD/CAM) systems as digital technologies have been introduced to the dental field to produce prostheses using machines and computers, allowing the workflow of digital veneering and quality standardization of dental restorations using of restorative materials. This study included all the studies which focused and reported the CAD/CAM systems. A filtration procedure was used to remove duplicates and irrelevant publications. The online databases PubMed and Google Scholar were used to perform a literature search for publications published until 2020, without any date or language restrictions. We used a combination of relevant search terms, such as “computer-aided design, CAD/CAM, dentistry, dental fabrication, restoration, restorative materials". We independently identified publications and systematically screened titles, abstracts, and full texts of the collected publications. Among 15 articles initially selected based on the title and abstract, 6 articles were excluded. Finally, 7 articles were selected and included in the review. There was no doubt that CAD/CAM modified the world of dentistry. The review concluded that several digital technologies, such as CAD/CAM systems are being used in various dentistry specialties. The application of CAD/CAM technology had many advantages with few limitations.

Keywords: Computer-aided design, computer-aided manufacturing, dentistry, dental fabrication, restoration, restorative materials.

Introduction

The digital revolution has recently been applied worldwide by using digital electronics technology based on computers instead of mechanical and electronic technology [1]. In the dental field, several digital technologies have been introduced, such as computer-aided design and computer-aided manufacturing (CAD/CAM) systems [2], to produce prostheses using machines and computers [3]. CAD/CAM technology permits the workflow of digital veneering [4] and automates the process of production and quality standardization of dental restorations [5], via using restorative materials such as zirconia reinforced lithium silicate, hybrid ceramics, oxide ceramics (yttria-stabilized zirconia), and resin nano-ceramics [6]. Resin-infiltrated filler scaffolds and hybrid ceramic are new materials for CAD/CAM applications that were fabricated through the industrial process [7]. During the dental restoration process, CAD/CAM systems digitally transformed the clinical situation into a three-dimensional data set through direct/indirect digitalization [5]. The CAD/CAM system consists of three main components: a scanner (digitalization tool), scanning the digital data to be processed by the computer. Design software using CAD software that produces a set of data about the product to be fabricated and design the prosthesis. Besides, the production technology uses processing machines or equipment that transforms the data to the desired product and produce restoration [3]. CAD/CAM systems are classified according to the CAD/CAM system’s location; in the dental field, it is classified into a chair-side CAD/CAM system, laboratory CAD/CAM system, and centralized fabrication [8]. CAD/CAM system is considered as an economical and reproducible and applicable way to achieve unique models [9]. It acquired the confidence of the profession and the patients due to the provided restoration’s comfort and ease. Its restorations are more esthetically pleasing, durable, festering, and marginally adaptive than the conventional repairs. However, CAD/CAM technology has some disadvantages, such as its cost, which is considered the

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main issue is restricting its use [10]. Therefore, this review's objective was to identify the main advantages and disadvantages of using CAD/CAM technology. Also, investigate its application and how it impacts the quality control and productivity in the dental field.

Literature Search

A filtration procedure was used to remove duplicates and irrelevant publications. The online databases PubMed and Google Scholar were used to perform a literature search for publications published until 2020, without any date or language restrictions. We used a combination of relevant search terms, such as "computer-aided design, CAD/CAM, dentistry, dental fabrication, restoration, restorative materials" We independently identified publications and systematically screened titles, abstracts, and full texts of the collected publications. Among 15 articles initially selected based on the title and abstract, 6 articles were excluded. Finally, 7 articles were selected and included in the review.

Discussion

CAD/CAM components

Scanner

The scanner measures three-dimensional tooth and jaw structures and then transforms them into digital data via optical scanners or mechanical scanners. Some of the optical scanners are es1 (etkon, laser beam), Everest Scan (KaVo, white light projections), and Lava Scan ST (3M ESPE, white light projections). The light source is the white light projection or a laser beam. A solid angle is the receptor unit; using the receptor unit's image, the computer could calculate a three-dimensional data set [11]. Mechanical scanners in the dental field include one example, which is the Göteborg: Procera Scanner from Nobel Biocare. In this type of scanner, a ruby ball was used to read the master cast mechanically by measuring the three-dimensional structure. This type of scanner is characterized by high accuracy due to adjusting the ruby ball's diameter to the smallest grinder in the milling system that enabled all collected data to be milled [12].

Design software

Design software for dental restorations, the framework of the crown, and fixed partial dentures (FPD) could be constructed, on the one hand, and full anatomical crowns, partial crown, adhesive FPDs, and inlays retained FPDs could be designed on the other hand [13].

Processing devices

The data that were provided by the CAD software were transformed into milling strips for the CAM processing and loading into the milling device. Processing devices have three milling axes that can move in three spatial directions, making it simple by taking a short milling time, for example, Lava (3M ESPE). The 4-axis milling devices, such as Zeno (Wieland-Imes), had three spatial axes and a tension bridge. The 5-axis milling devices had three spatial dimensions and the rotatable tension bridge (4th axis) could rotate the milling spindle (5th axis) that enabled complex geometries with subsections to be milled [3].

Types of CAD/CAM production in dentistry

CAD/CAM restorations can be produced in three different ways according to the CAD/CAM system's location: chair-side production, laboratory production, and centralized production [3,10].

Chair-side production

In this production concept, the CAD/CAM system components are located in the dental surgery. It includes taking a chair-side impression, and then the patient's dental restoration is produced simultaneously without the involvement of the laboratory procedure using an intraoral camera as a digitalization instrument. Although this procedure saves patient's time, it is very expensive and needs high cost [3,10].

Laboratory production

This type is equivalent to the conventional method; after taking the impression, the dentists sent it to the laboratory. But the other steps of the CAD/CAM production are performed in the laboratory via the technician using the scanner [3,14].

Centralized production

The first and second steps of dental prostheses' output occurred in the laboratory, but the third happened in the milling center. The impression was taken and the master cast was digitized in the laboratory. It was sent to the outsource lab through the connection between the satellite scanners in the dental lab to the production milling center through the Internet. In the outsource lab, the data were sent to the production center for restoration by using the CAD/CAM device, then the final restoration was fabricated and sent to the dentist [3,10].

Materials for CAD/CAM processing in dentistry

Different materials can be processed on dental CAD/CAM devices, such as metals, resin materials, silica-based ceramics, infiltration ceramics, and oxide high-performance ceramics.

Metals

Metals, like chrome cobalt alloys, titanium, and titanium alloys, using the dental milling devices (Everest Bio T-Blank (KaVo, pure titanium), have been processed because these metals have high attrition and extra materials costs and their milling is of no economic interest.

Resin materials

Resin materials can be used for the casting technology through milling of lost wax frames. Resin materials can be used as crown and FPD frameworks for full anatomical long-term temporary prostheses or long-term provisional.

Silica-based ceramics

Silica-based ceramics are offered through various CAD/CAM systems to produce the inlays, lies, partial and full crowns, and veneers—lithium disilicate ceramic blocks used for full anatomical anterior and posterior crowns because of their high stability values. Chair-side application used glass–ceramics to provide aesthetically pleasing results because of the high similarity in the structures between the glass–ceramics and the natural tooth.

Infiltration ceramics

Infiltration ceramics originated from the Vita In-Ceram system (Vita) and is presented as follows: Vita In-Ceram Alumina (Al2O3), Vita In-Ceram Zirconia (70% Al_2O_3, 30% ZrO_2), and Vita Vitablocs Mark II (VITA) In-Ceram Spinell ($MgAl_2O_4$).

Oxide-high performance ceramics

Oxide-high performance ceramics related to CAD/CAM technology, aluminum oxide (Al_2O_3), and zirconium oxide (ZrO_2) are presented as blocks.

Methods of data acquisition in CAD/CAM technology

Different methods can be used to collect CAD data, such as intraoral scanning, contact and noncontact digitization, and CT scan or magnetic resonance imaging (MRI). Regarding intraoral scanning, this method takes a 3-D virtual image of the prepared tooth and their adjacent structures to the patient's mouth, then to CAD to design the prosthesis [15]. Some considerations should be taken via dentists while taking the digital impression, such as hemostasis, moisture control, and the soft tissue retraction. Contact and noncontact digitization: after producing the model, the conventional impression was taken and the data were transferred to CAD through contact digitization, the probe that was concerned with reading the model's anatomy, or noncontact digitization, such as laser light, charged-coupled devices, and optics. Therefore, noncontact digitization was more rapid in the data collection process due to lack of physical contact with the model, compared to contact digitization. CT scan/MRI: computed tomography and MRI are more advanced techniques for collecting data for CAD/CAM technology by capturing a picture that was then transferred to CAD. CT data can be used in the hard tissue model like the bone, while MRI data can be used in the model of soft tissues [16].

Application of CAD/CAM in the dentistry

CAD/CAM systems have been used in varied specialties of dentistry, such as orthodontics, prosthodontics, Maxillofacial prosthetics, and implant dentistry. In orthodontics, due to patients being annoyed by the wires and the metallic brackets, CAD/CAM system fabricated these metallic brackets and wires for the invisible lingual bracket system. Also, CAD/CAM technology could be used for orthodontic mini-implants [17]. Therefore, this system gained popularity due to esthetics. In prosthodontics (fixed or movable), CAD/CAM system fabricated them [18] as follows: (a) removable complete dentures: several studies have proposed the fabrication of removable complete dentures via CAD/CAM system, but no trials yet. (b) removable partial dentures: CAD/CAM could produce the partial denture framework by using the additive prototyping technique. (c) Crowns/bridges: CAD/CAM technology can fabricate the crown and the bridge using the Zirconia material that showed significant clinical results. (d) inlay, onlay, and veneers restorations could be produced through CAD/CAM. in Maxillofacial prosthetics: CAD/CAM system could fabricate the artificial nasal/ear prosthesis, as well as CAD/CAM could treat any defect in the bone after removing tumors or trauma through manufacturing the implants [10,19]. In implant dentistry, CAD/CAM could produce the implant abutments for implant placement [20].

Advantages and disadvantages of CAD/CAM technology

CAD/CAM technology has many advantages regarding the fabrication process [21], such as the application new materials, cost-effectiveness, increased quality control, and reduced labor. Increasing the quality of dental prostheses through standardized production processes increases the efficacy of quality management possible. CAD/CAM technology, due to improving the quality control, increased productivity that had a positive effect on the dental laboratory to be computerized production centers. CAD/CAM allowed the application of interesting new materials, such as titanium and ceramics, with high performance accurately. CAD/CAM, by increasing productivity, led to increasing the competitive capability of producing dental prostheses which kept the business volume in high-wage countries [3].

Additionally, CAD/CAM provided a quality restoration with rapid fabrication. The chair-side system allowed patients to get their dental restoration at the same time [10]. Also, using CAD/CAM technology prevented the degradation process, such as residual strain, by providing reproducible processing and designing optimal shapes according to the materials [21]. Concerning the reduction of the labor, the application of the CAD/CAM system reduced the labor by the production of the ceramic molar crown, and with leucite-reinforced porcelain with DECSY®, the measurement took 4 minutes, the design took 1 minute, transforming the data took 2 minutes, and

following-up processing with ceramics took 90 minutes. This consumed time was shown to be shorter than that consumed through conventional techniques [21]. They applied the CAD/CAM system to save the processing data and follow-up during the machine's available time. These advantages are not available with the conventional technique.

Even though there are some drawbacks/disadvantages of the CAD/CAM fabrication technology, the machine's extra investments exceeded small laboratories' budgets. Additionally, there are limitations of some applications due to the procedures of the software and production. The cost remains a huge issue with CAD/CAM application. Dentists face a huge challenge during taking the digital impression because they should be very careful about the retraction of the soft tissue and moisture control [3,10].

Future perspectives for dental CAD/CAM

The application of CAD/CAM is a promising technology to achieve quality control in all dental fields. Successful application of CAD/CAM technology is expected to be applied for the removable partial denture frameworks' fabrication [22,23] and the fabrication of super implant structures and orthodontic devices. The availability of CAD/CAM technology is also anticipated in educational settings as training tools during a normal dental practice day with explanatory materials for patients and simulations of surgical procedures [24].

Conclusion

Several digital technologies have been introduced to the dental field, such as CAD/CAM systems to produce prostheses using machines and computers. CAD/CAM technology: CAD/CAM systems have been used in various dentistry specialties. The application of CAD/CAM technology has several advantages and disadvantages to this technology. It needs more studies for these technologies in the future.

List of Abbreviations

CAD Computer-aided design
CAM Computer-aided manufacturing

Conflict of interest

Not applicable.

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Consent for publication

Not applicable.

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