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Exploring the Impact of CAD/CAM Technology in Prosthodontic Dentistry

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ABSTRACT

In recent years, the integration of CAD/CAM (Computer-Aided Design and Computer-Aided Manufacturing) technology has revolutionized various sectors of dentistry, particularly in the realm of Prosthodontics. This innovative approach offers both advantages and disadvantages, reshaping the landscape of dental practice. Let's delve into the fundamental aspects of CAD/CAM technology and its application in Prosthodontic dentistry.

Keywords: CAD/CAM- prosthodontics- Implant - surgical guides- maxillofacial

INTRODUCTION

CAD/CAM technology, short for Computer-Aided Designing and Computer-Assisted Manufacturing, has significantly advanced the field of dentistry and prosthodontics. By utilizing CAD/CAM systems, dental professionals can enhance the design and production of various dental restorations, particularly dental prostheses like crowns, veneers, bridges, implants, and dentures.

Originating in the 1960s for aerospace and automotive industries, CAD/CAM found its way into dentistry by the 1980s. Its dental application took a significant step forward in 1989 when Mormann & Brandestinni introduced CAD/CAM technology in Germany. Since then, CAD/CAM has become an integral part of all branches of prosthodontics, enabling the design and machining of restorations with exceptional accuracy and precision.

Over the past 25 years, CAD/CAM has gained immense popularity, revolutionizing treatment methods and prosthetic fabrication. While it's well-established in fixed prosthodontics, its use in removable prosthodontics is still emerging. The introduction of CAD/CAM for complete dentures followed its success in implant and fixed prosthodontics. This technology offers a new approach to the design and fabrication of complete dentures, although its use was initially limited by the availability of suitable CAD software.

Overall, CAD/CAM technology continues to evolve, promising further advancements in dental treatment concepts and prosthetic fabrication techniques.

Advantages of CAD/CAM systems

- No Traditional Impressions
- Produce Chair-side Restorations.
    - Less appointment.
    - High Precision and Accuracy.

- Improve the Qualities of Restoration.
- Eliminates the Use of the Laboratory Equipments required for Conventional LOST-WAX technique.
- Speed, ease of use, and quality Digital scans.
- Faster design and fabrication.
- Natural appearance CAD/CAM restorations.

Limitations of CAD/CAM systems

- Initial High Cost of CAD/CAM Systems.
- Time and Cost Investment to Master the technique

CAD/CAM Components Scanners:

Currently, the data acquisition is either performed directly in the patient's mouth (intraoral) or indirectly after taking an impression and fabricating a master cast (extraoral).[11]

Basically, there are two different scanning possibilities:

Optical scanners

The basis of this type of scanner is the collection of three-dimensional structures in a so-called 'triangulation procedure'. Here, the source of light (e.g.: laser) and the receptor unit are in a definite angle in their relationship to one another. Through this angle the computer can calculate a three-dimensional data set from the image on the receptor unit. Either white light projections or a laser beam can serve as a source of illumination.

Mechanical scanners

In this scanner variant, imagine a tiny ruby ball moving across the surface of the master cast, tracing each line meticulously. It's like a tiny explorer, mapping out the three-dimensional landscape with precision. This method boasts incredibly accurate scans, ensuring that even the smallest details are captured. The size of the ruby ball is carefully calibrated to match the finest grinder in the milling system, ensuring that every bit of data collected can be translated into physical reality through milling.

However, there's a downside to this mechanical marvel. The intricate mechanics behind it make the scanner quite pricey, and it takes longer to process compared to simpler optical systems. So, while it's excellent at what it does, it comes with a hefty price tag and requires a bit more patience during the scanning process.

Design software

The software mentioned is like a digital artisan, transforming captured images into intricate digital models for crafting prostheses with precision. Think of it as a virtual sculptor, meticulously shaping and designing dental restorations based on the captured data.

It's akin to having a specialized toolbox provided by manufacturers, constantly evolving to offer new and improved features through regular updates. These updates ensure that users always have access to the latest advancements in construction techniques.

To facilitate compatibility and seamless integration, the software typically employs standard transformation language (STL) data as its foundation. However, some manufacturers may opt for proprietary data formats tailored to their specific needs. This specialization, while enhancing efficiency, can sometimes lead to incompatibility between different construction programs.

Digital fabrication process tools

In the final stage of the dental CAD/CAM process, the focus shifts to bringing the virtual design to life in the tangible world. This involves transforming the digital blueprint of a restoration into a physical form ready for processing, refining, and polishing before it can be seamlessly integrated into the patient's oral cavity.

There are two primary approaches to accomplish this: subtractive manufacturing and additive manufacturing. Subtractive manufacturing, often achieved through milling and grinding, entails carving out the desired shape from solid blocks of material. Milling units, which come in various configurations, such as dry/wet milling and grinding, sculpt the restoration with precision. The sophistication of these units is evident in their ability to move along multiple axes (3, 4, or 5), allowing for intricate detailing in the X, Y, and Z dimensions.

On the other hand, additive manufacturing, also known as 3D printing or Rapid Prototyping (RP), builds objects layer by layer from digital models. Once the CAD design is finalized, it undergoes segmentation into multislice images. Each millimeter of material corresponds to multiple layers (ranging from 5 to 20), which the machine deposits sequentially. These layers, composed of liquid or powder material, fuse together to form the final restoration shape.

Whether through subtractive or additive means, the aim remains consistent: to craft precise, high-quality dental restorations that meet the patient's needs with efficiency and accuracy.

After that, we go through more refining steps to get rid of any extra material and the supporting structure. The tricky part with this kind of manufacturing is that it might lead to variations in the final product due to shrinkage during the building process, post curing, and the thinness of the layers used. There are various methods in additive technology, like Direct Metal Laser Sintering (DMLS), Stereo Lithography (SLA), Scan, Spin, and Selectively Photocuring (3SP), Poly Jet, and Direct Light Projection (DLP). The main thing that sets these methods apart is how they handle the vertical aspects, or the z-plane, of the creations.

CAD/CAM systems in dentistry

Depending on the location of the components of the CAD/CAM systems, in dentistry three different production concepts are available:

1. Chairside Production/Office-Based Devices

2. Laboratory Production

3. Centralized fabrication in a production center.

Chairside/office production

In the bustling hub of the dental clinic, the CAD/CAM system stands like a conductor orchestrating the creation of dental restorations right at the patients chairside. Imagine it as the maestro, seamlessly blending technology and dentistry into a harmonious symphony of efficiency and convenience.

At the heart of this system lies the digitalization instrument, the intra-oral camera, which is like the artist's brush, replacing the need for traditional impressions in most cases. It captures the intricate details of the oral landscape with precision, paving the way for indirectly fabricated restorations in a single appointment.

Among the star performers in this ensemble are four distinguished products: CEREC AC, E4D Dentist, iTero, and Lava COS (Fig 1,2, 3). Each brings its own unique flair to the stage of digital impressions, offering dentists a palette of options to choose from.

Fig. 1: iTero intraoral scanner with sealed keyboard, wireless mouse, and wireless foot pedal; parallel confocal imaging enables powder-free scanning

With digital impressions, gone are the days of selecting trays, mixing materials, and waiting for them to set. No longer do we have to deal with the aftermath of messy impressions or the hassle of disinfecting and shipping them to a laboratory. Instead, the spotlight shines on the seamless workflow facilitated by these cutting-edge devices.

CEREC and E4D steal the show with their ability to not only capture images but also to design and mill restorations right in the office, promising same-day smiles for patients. Meanwhile, iTero and Lava COS (Fig: 2) take centre stage for their prowess in image acquisition, each employing its own distinctive method.

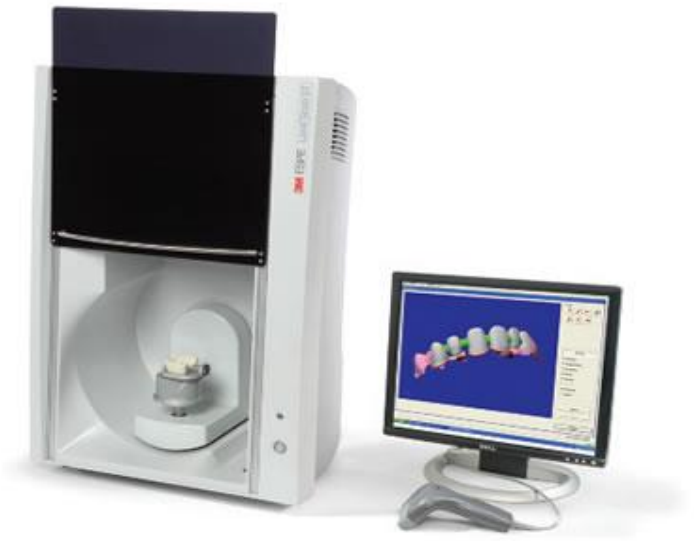

Fig 2: Lava CAD/CAM System

The CEREC series, a pioneer since 1986, captures multiple images with a still camera, weaving them together with software wizardry. E4D, on the other hand, dazzles with its use of a red-light laser, sparing the need for powder in most cases, simplifying the process while maintaining precision.

iTero brings its own flair, utilizing a combination of still images and a strobe effect, along with a gentle probe to ensure optimal focus without the need for powder. And then there's Lava COS, a true innovator, offering a continuous video stream of the teeth, revolutionizing the digital impression process.

Yet, amidst the diversity of these systems, a common thread emerges— the commitment to excellence and efficiency. Even as CEREC and Lava COS may still require a sprinkle of powder for the cameras to register the tooth's topography, the process remains streamlined, ensuring a seamless experience for both dentist and patient alike.

Laboratory production

This variant of production is the equivalent to the traditional working sequence production between the dentist and the laboratory. The dentist sends the impression to laboratory where a master cast is fabricated first. The remaining CAD/CAM production steps are carried out completely in the laboratory. With the assistance of a scanner, three-dimensional data are produced on the basis of the master die. These data are processed by means of dental design software. After the CAD-process the data will be sent to a special milling device that

produces the real geometry in the dental laboratory. Finally, the exact fit of the framework can be evaluated and, if necessary, corrected on the basis of the master cast. A major advantage of using CAD/CAM systems in the laboratory is that the final restoration can look exactly like the provisional. CAD/CAM systems also shorten the learning curve for new dental technicians, although a dental technician still finishes each restoration by hand. CAD/CAM technology does not replace the need for skilled dental laboratory technicians.

Centralized production

The third option of computer-assisted production of dental prostheses is centralized production in a milling centre. In this variation, it is possible for ‘satellite scanners’ in the dental laboratory to be connected with a production centre via the Internet. Data sets produced in the dental laboratory are sent to the production centre for the restorations to be produced with a CAD/CAM device. Finally, the production centre sends the prosthesis to the responsible laboratory. Thus, production steps 1 and 2 take place in the dental laboratory, while the third step takes place in the centre. This production model minimizes the cost to the laboratory and has the potential to improve fabrication efficiencies.

CAD/CAM in different fields of prosthetic dentistry CAD/CAM in removable prosthodontics, fig3.

Brand	iTero Element	TRIOS 3 (Wireless)	True Definition / Mobile True Def.	CEREC Omnicam A
Communications	Incognito, Invisalign, Sure smile	3Shape Connection TRIOS® Ready Ortho, Incognito, Invisalign[D] Sure smile, Clear correct···	Trusted Connection Incognito, InvisalignF Sure smile, Clear correct···	Sirona Connection CEREC (CAD/CAM), CERC Ortho, Invisalign, Clear correct··· Dolphin, OnyxCeph···
Official price	NT $1,300,000[A]	NT$1,080,000–1,220,000[C,E]	NT$1,000,000[G]	NT$2,400,000[I]
Appearance				
Specifications	A. Three-year warranty is included in this price. B. Pen-grip or handle type are both available with the Cart or Pod model. C. Only includes basic software; others must be purchased separately. D. A contract between Align Tech and 3Shape for accepting digital scans from TRIOS scanners was terminated in the US on Jan 31, 2018. E. Annual fee is an additional charge.	F. Trusted connections with Invisalign® only in the Advanced Data Plan G. The first-year annual fee is included in this price.	H. STL not natively available without additional cost.[28] I. Includes CEREC Ortho	
General notes	J. Communication services from the providers listed may vary among regions. K. All of the above information acquired from the official websites, press releases, and product brochures of the four scanners. L. Photos shown in Appearance were sourced from official websites or brochures; all copyright belongs to the original companies. M. All data relate to the latest update, as of January 2018. N. Information interpretation may differ slightly from the origin, in order to present a unified comparison table. O. Further resources listed in the References.			

The fabrication of complete dentures using a computer-aided design/computer-aided manufacturing (CAD/CAM) system has the potential to simplify the above process and resolve the associated problems. In recent years, CAD/CAM systems have been successfully introduced into restorative dentistry and maxillofacial technology. Moreover, they have been applied to removable prostheses. Regarding the removable partial denture, the framework design is drawn on the working cast and then scanned using a laboratory scanner. The framework is always fabricated by printing a photo polymeric framework and then cast with

chromium cobalt, or the framework can be printed directly from chromium cobalt through Direct Metal Laser Sintering.

CAD/CAM technology in implant prosthodontics

CAD/CAM allows simplified production of precise and durable implant components. The precision of fit has been proven in several laboratory experiments and has been attributed to the design of implants. Milling also facilitates component fabrication from durable and aesthetic materials. The CAD component virtually designs the 3D contour of the final implant component. The CAM system produces the actual implant component according to the virtual design. In implant dentistry, the implant abutments and frameworks are produced by milling at a central production facility. Examples of these systems are Procera (Nobel Biocare), Etkon (Straumann), CAMStructure (Biomet 3i), and Atlantis (Astra Tech). Custom CAD/CAM abutments combine most of the advantages of stock and cast custom abutments.

CAD/CAM in manufacturing surgical guides

The conventional surgical guides were used as a control for the manual check of the deviation of the implant axis. The direct transfer of the digital planning data allows the fabrication of surgical guides in an external center without the need of physical transport, which reduces the logistic effort and expense of the central fabrication of surgical guides. Bibb et al. described the fabrication of stainless-steel surgical guides for the placement of dental implants for prosthetic retention using SLM technology. It was first reported for the manufacture of custom-fitting surgical guides.

CAD/CAM technology in maxillofacial prosthodontics

CAD/CAM is widely used for the fabrication of maxillofacial prostheses, extraoral radiation devices, individual respiratory masks and facial protection devices etc. Three-dimensional surfaces imaging is done by using CAD software. This 3-D surface image aids in the fabrication of resin model with Lithographic technique and then wax pattern is made. Of this completed wax pattern, once again computer assisted three-dimensional imaging is done. Data is entered in computer and prosthesis is milled by computer aided milling machine. Thus, a silicone maxillofacial prosthesis is fabricated using CAD/CAM technology.

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