Review Article

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PROSTHODONTICS IN THE DIGITAL AGE: A REVIEW

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ABSTRACT:

Digitalization is the integration of digital technologies into everyday life by the digitization of everything that can be digitized. All aspects of life are getting digitalized in the present time, including dentistry. From the introduction of computer-aided designing/computer-aided manufacturing into dentistry in the 1980s to the application of digital impressions, cone beam computed tomography and jaw tracking devices presently, dentistry and specifically Prosthodontics have entered the digital age. The present review aims to highlight the various areas of prosthodontics where digitization has had an impact and the various advantages it has over conventional techniques. For discussion these advancements have been discussed under the clinical and laboratory aspects. There is an endless scope of digitization and technological advancements in prosthodontics. With future research going on in the areas of optical coherence tomography, nano-optics, lasers and 3-D printing technology, the future of digital dentistry is bright.

Key-words: Digitization, Digital Technology, Virtual Dentistry, Advances in Prosthodontics, CAD/CAM, CBCT, Digital Impressions, Stereolithography

INTRODUCTION

Innovation and improvement in oral health and the techniques used to diagnose, prevent, and intervene in providing optimal oral health is a continuous process. Dentistry can be dated back to the eighteenth century, when impressions meant use of waxes and plaster of Paris[1]; and the dental equipment consisted of hand driven and later water driven motors. From then there's been a long journey to achieve the contemporary paraphernalia.[2,3,4] Dentistry's earliest innovations were highlighted in diagnostics (e.g. radiography) and followed by prevention (e.g., understanding of biofilm-mediated disease and the discovery of fluoride's role in caries prevention). Recent decades have seen innovation in therapeutic technologies such as the acid etch technique and osseointegrated dental implant. Today, therapeutic interventions involve digital diagnostic, treatment planning, and prosthesis design/manufacturing techniques that are revolutionizing patient care. [5]

In the clinical aspect, digitization has revolutionized imaging and diagnostic options. While the information gleaned from a dental radiograph is substantial, there are limitations associated with the use of a two-dimensional image.[6] Cone beam computed tomography (CBCT) provides images of high contrasting structures and is therefore particularly well-suited towards the imaging of osseous structures of the craniofacial area. The use of CBCT technology in

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clinical dental practice provides a number of advantages for maxillofacial imaging. [7]

Impression making, an important tool in treatment planning as well as prosthesis fabrication, conventionally involves the use of impression materials like elastomers and elastic impression materials. Digital impression making, on the other hand, requires the operator to scan the teeth and tissues with an intraoral scanner. The resulting impression is automatically stored as digital data and is much more accurate.[8]

On the laboratory side, computer-aided design/computer-aided manufacturing (CAD/CAM) of prosthetic crowns/bridges is available. Development in the field of CAD/CAM gained momentum in the 1980s. The first CAD/CAM prototype was patented by Dr. Duret in 1984. Conventionally, prosthesis fabrication includes making a wax pattern, investing, casting, ceramming and finishing of the crown/bridge. A CAD/CAM machine enables the technician/dentist to plan, fabricate and deliver the prosthesis with the help of digital software and additive/subtractive manufacturing. CAD/CAM technology, stereolithography, rapid prototyping, use of virtual articulators etc. has digitized the lab procedures. [9]

The modern dental practice has endless options for preserving oral and stomatognathic health and can provide next to natural aesthetics with an enhanced approach, reduced treatment time, minimized error potential and better quality assurance. [9] The present review aims to highlight the effects of digitization on various aspects of prosthodontic treatment and the advantages that it has over conventional techniques.

DIGITIZATION IN PROSTHODONTICS

The evolution of digitization in the field of prosthodontics can be categorized in the following way:

1. Diagnosis and Treatment Planning:
   a. Imaging techniques
   b. Digital impressions
   c. Occlusion and jaw movement analyzers
   d. Jaw Tracking devices
   e. Patient management software
2. Clinical Procedures:
   a. Removable prostheses
   b. Fixed prostheses
   c. Implants
   d. Maxillofacial prosthetics
3. Laboratory Procedures:
   a) Computer-aided designing/computer-aided manufacturing (CAD/CAM):
      i. Subtractive manufacturing
      ii. Additive manufacturing:
         a) Stereolithography
         b) Inkjet-based systems or 3-D Printing
         c) Selective Laser Sintering
         d) Fused Deposition Modeling
   b. Virtual articulators

DIAGNOSIS AND TREATMENT PLANNING

Imaging Techniques

The introduction of panoramic radiography in the 1950s and its widespread adoption throughout the 1970s and 80s heralded major progress in dental radiology. Digital panoramic radiography systems became available by 1995. However, both intraoral and extraoral procedures suffer from the same inherent limitations of all planar two-dimensional (2D) projections. Numerous efforts have been made towards three-dimensional (3D) radiographic imaging and while computed tomography (CT) has been available, its application in dentistry has been limited. The introduction of CBCT specifically dedicated to imaging the maxillofacial region heralds a true paradigm shift. [7]

CBCT is accomplished using a rotation in which a pyramidal- or cone-shaped x-ray beam is directed towards an area x-ray detector on the other side of the patient's head. Cone-beam geometry has inherent quickness in volumetric data acquisition and uses a comparatively less expensive radiation detector (Figure 1). Herein lies its potential for significant cost savings and reduced radiation exposure. [7]

It has been reported that the total radiation is approximately 20% of conventional CTs and equivalent to a full mouth periapical radiographic exposure. CBCT can therefore be recommended as a dose-sparing technique compared with alternative standard medical CT scans for common oral and maxillofacial radiographic imaging tasks. The images are comparable to the conventional CTs and may be displayed as a full head view, as a skull view, or as localized regional views. [10] The uses of CBCT technology are in[11]:

1. Diagnosis.
2. Clinical applications.
3. Clinical evaluation of treatment outcomes.

Digital impressions

The philosophy for today's traditional impression materials began in the mid-1930's with the introduction of reversible hydrocolloids. By the 1950's polysulphides were introduced and for the first time an elastomeric material was employed. Though an improvement in reproducing the characteristics of prepared teeth, there were still inherent problems. Consequently, digital approaches were created to circumvent the traditional obstacles of the existing impression materials.

The first optical impression unit was introduced by Sirona Dental Systems under the CEREC name. The principle is based on a "point and click" technology which strings together a number of individual pictures of the same object. More recently, 3M ESPE introduced the Lava C.O.S. (Chairside Oral Scanner) system. The main improvement to the original digital scanner was the use of 3D-in-motion technology. This technology, in contrast to the "point and click" systems, captures continuous 3D video images and displays these images in real time on a touch screen monitor

(Figure 2). Once the image is captured and stored, it is then electronically transferred to the dental laboratory. Subsequently, models for the case are fabricated using stereolithoghraphy, which allows the technician to complete the restoration. [12]

There are two classifications of digital dental impression devices[13]:

- CAD/CAM devices that include an intraoral digital scanner for capturing impressions of the prepared teeth, as well as synchronized units for both designing and milling the restorations from blocks of ceramic or composite materials
- Dedicated intraoral digital scanners that capture data that can be sent to laboratories and other facilities, where stereolithic or milled models and dies are created from the data, which are then articulated and sent to dental laboratories for the custom fabrication of the restorations.

Advantages over conventional impressions:

1. Digital impressions eliminate the uncomfortable experience of making a physical impression.
2. Digital impressions are an incredible teaching and evaluation tool because tooth preparation can be checked and corrected in real time.
3. The image on the monitor shows if all the needed data has been captured before sending it to the lab.
4. Disinfection of impressions is a non-issue with a digital system.
5. Digital impressions can be stored indefinitely as data in a computer and thus help in recordkeeping.
6. Virtual models can be obtained.

Occlusion and Jaw Movement Analyzers

Occlusion analyzing systems are available to measure occlusal forces and quantify how well balanced a patient's occlusion is. Conventionally, strips of articulating paper are used to indicate contacts in occlusion. These, however cannot:

- differentiate between centric and eccentric contacts and,
- cannot predict the magnitude and direction of occlusal forces.

The T-scan (Tekscan) and Dental Prescale Occluzer (Fuji Film Co.) are two such systems for occlusal analysis which bring objective precision measurement to the largely subjectively analyzed discipline of occlusion.

T-Scan System

Since its inception in 1984, this technology has undergone much evolution over the past 30 years beginning with T-Scan I, then T-Scan II for Windows, to T-Scan III with Turbo recording, to the present day version known as T-Scan 8.

Present day Computerized Occlusal Analysis technology records and quickly displays for clinical interpretation, tooth contact timing sequences and tooth contact, fluctuating relative occlusal force levels, which occur during functional mandibular movements. These occlusal data measurements are recorded intraorally with an ultra-thin, mylar-encased sensor that is connected to a computer workstation via a USB interface. This sensor is placed between a patient's teeth to record changing tooth-tooth contact interactions. The displayed relative occlusal force and timing data aids in the examination and treatment of occlusal abnormalities on natural teeth, dental prostheses, and dental implant prostheses.[14]

T-Scan Applications in Implant Prosthodontics:

The occlusal forces that are applied to an implant prosthesis can be a potentially destructive factor in shortening the potential longevity of any implant prosthesis. Poorly directed and non-uniform occlusal loading will torque a prosthesis and apply stresses that may ultimately result in prosthetic failures. With the aid of the T-Scan Occlusal Analysis System, occlusal forces that are applied to an implant prosthesis can be quantitatively represented for improved correction through occlusal adjustments.[15]

Denar Cadiax System

Using the information resulting from the patients' jaw movements, dentists can reproduce occlusal surface forms of the restorations in accordance with the patients' teeth and available restorations. These data can also be used for articulator settings, improving of the diagnosis and treatment of temporomandibular joint disorders (TMDs), and analysis of the patients' occlusion. Numerous approaches have been reported to record mandibular movements. Conventionally prosthodontists use interocclusal wax records for condylar guidance settings. However, the accuracy of this method is questionable. Electronic pantographs were introduced in 1983 to minimize errors occurring in the transferring procedure and to improve the efficiency. The Denar Cadiax is one such system. It eliminates the need to rely solely on inter occlusal or average settings to program the articulator and enables precise recording of all jaw movements.[16]

Jaw Tracking Devices

If transitional occlusal contact points on dentition during functional jaw movements can be observed graphically, it will dramatically improve the realization and evaluation of dental occlusion for both research and clinics. This technology is now available with the help of jaw tracking devices. Visualization of occlusion requires a three-dimensional configuration record of the maxillary and mandibular dentitions and six-degree-of-freedom jaw movement data with a 10 micrometre accuracy level.[17]

Planmeca 4D Jaw Motion System

This is a CBCT integrated solution for tracking, recording, visualising and analysing jaw movements in 3D. With Planmeca 4D Jaw Motion, it is possible to measure and record the movement path of one or more points of interest in a 3D image. For occlusion analysis, digital dental models can be aligned with a CBCT image. These jaw tracking devices can also be used to study the occlusal contacts. Jaw movement data obtained from these devices can be super-imposed onto virtual 3-D models (obtained by scanning actual patient models) and the resulting data is used to calculate the minimum distance between the maxillary and mandibular occlusal surfaces. [17]

Patient Management Software

Dental practices usually employ the services of auxiliary staff for practice and patient management. Software are available that can enable the dentist or auxiliary staff to manage everything entirely via a computer system. This allows a completely paper-free practice.

MOGO is one such Dental Practice Management software. Powered by the Microsoft Cloud, it provides features like appointment booking, clinical charting, eReminders, imaging, paperless practice, business reports and word processor. AeronaClinic, by Aerona Software Ltd, is another cloud based Practice Management solution which is web based.

CLINICAL PROCEDURES

Removable Prostheses

Recently, CAD/CAM technology has become commercially available for fabrication of complete dentures with the introduction of commercially available systems like AvaDent (AvaDent Digital Dental Solutions) and Dentca (Dentca, Inc.). [18]

The entire digital CAD/CAM process consists of the following appointments:

1. Impressions.
2. Jaw relation records.
3. Occlusal plane orientation.
4. Tooth mould and shade selection.
5. Maxillary anterior tooth positioning record.
6. Placement of dentures.

The AvaDent denture technique uses an Anatomical Measuring Device (AMD) that can be adjusted to the desired occlusal vertical dimension and then used to maintain that dimension while centric relation is recorded using the incorporated gothic arch tracing plate and stylus. The AMD is also used to determine the correct amount of upper lip support, the position of the maxillary six anterior teeth, and the desired mediolateral orientation of the occlusal plane. In addition, there is an occlusal plane orientation ruler that can be inserted into the maxillary AMD and used to record the alignment of the maxillary AMD with the interpupillary line to make it possible for the computer program to align the maxillary teeth with the interpupillary line. [18, 19]

The CAD/CAM process offers significant advantages to the dental practitioner and the patient[18]:

1. It is possible to record all the clinical data for complete dentures in one appointment (one to two hours).

2. Clinical chair time is reduced considerably, thereby providing the opportunity for a more cost-effective set of appropriately accurate complete dentures.
3. A repository of digital data remains available that allows for more rapid fabrication of a spare denture, a replacement denture, or even a radiographic or surgical template that aids in the planning and placement of dental implants in the future.
4. The digital data are associated with a specific practitioner, it is more likely that patients will return to the dentist who fabricated their first digital denture when future treatment is needed.
5. Because the denture base is fabricated by machining, polymerization shrinkage of the resin is eliminated, and the fit of the denture base is superior to that of conventionally fabricated denture bases.

Fixed Prostheses

Prof. Werner H. Mörmann and Dr. Marco Brandestini, at the University of Zurich in 1980, attempted to use new technology to fabricate ceramic crowns in a dental office clinically at the chairside of patients. This led to the development of the Chairside Economical Restoration of Esthetic Ceramics, or CEramic REConstruction (CEREC) system (Figure 3).

The CEREC system has been continually improved in terms of both apparatus and software. It has satisfactory long-term results. A recent iteration of the system can fabricate not only original inlays and onlays, but also crowns and the cores/frameworks of FPDs in both clinical and laboratory settings. [20]

Advantage of the CEREC system:

1. CEREC technology makes it possible to produce and integrate ceramic restorations in a single appointment.
2. Unlike other materials such as amalgam or gold, ceramic is more biocompatible and has tooth-like physical and esthetic qualities.
3. Digital impressions are more comfortable for patients than traditional impressions.
4. Time-intensive occlusion adjustments are not required.

The success rate of CEREC restorations is as high as 95.5% following a period of 9 years[21] and 84% after 18 years. [22]

Implants

For implant placement, conventional dental panoramic and periapical radiography are often performed with the patient wearing a radiographic template simulating the preoperative prosthetic design. However, these imaging techniques do not provide complete three-dimensional (3-D) information of the patient’s anatomy. In addition, conventional surgical templates have been fabricated on the diagnostic cast that will direct the bone entry point and angulations of the drill, but they neither reference the underlying anatomical structures nor provide exact 3-D guidance.[23, 24]

To overcome these limitations in dental implantology, current research has been dedicated to developing techniques that can provide optimal 3-D implant positioning with respect to both prosthetic and anatomical parameters. The introduction of CT, 3-D implant planning software, and CAD/CAM technology has undoubtedly been an important achievement in this field. The digital CT (also including CBCT) images derived in this way can be converted into a virtual 3-D model of the treatment area. This provides the practitioner with a realistic view of the patient's bony anatomy, thus permitting a virtual execution of the surgery in an ideal and precise prosthetically driven manner.[23]

Different approaches have been introduced to transfer this planned digital information to the clinical situation. Mechanical positioning devices or drilling machines convert the radiographic template to a surgical template by executing a computer transformation algorithm. Other approaches include CAD/CAM technology to generate stereolithographic templates (Figure 4) or bur tracking to allow for intraoperative real-time tracking of the drills according to the planned trajectory. The so called navigation systems visualize the actual position of the surgical instrument in the surgical area on the reconstructed 3-D image data of the patient on a screen. [23, 24]

Maxillofacial Prosthetics

Much early work regarding digital advancement in maxillofacial prosthetics involved making an anatomical form using rapid prototyping (RP) processes such as stereolithography or laminated object manufacture. This research, however, did not attempt to integrate the RP technologies into existing prosthetic practice or was limited to the production of an anatomical form that was used as a pattern for replication into more appropriate materials via secondary processes such as silicone moulds or vacuum casting. [25]

Later research attempted to use RP methods to produce moulds from which prosthesis forms could be moulded. Other researchers attempted to exploit the ability of the ThermoJet (3D Systems Inc.) process to produce prosthesis forms in a wax material that was comparable to the waxes used in the typical prosthetic laboratory[5]. Recent advances in technology, including a new generation of CT scanners and 3-D model-making RP systems, facilitate the production of facial prostheses. [25]

In one case report, the patient's ear was scanned using CT. Magics RP (Materialise) image ware was employed to provide interactive segmentation of the 3-D anatomy. The midline of the face was used as the axis of symmetry, and the image of the normal ear was extracted, mirrored, and placed on the side of the face with the deficiency. By a laminated object manufacturing (LOM) system, a paper ear model was made. Silicone was used to make a cavity block of the paper ear by vacuum casting. Then, according to the patient's skin color, pigment was added into the elastomer. Elastomer was poured into the silicone cavity to create a silicone auricular prosthesis. [6]

Design and fabrication of auricular prostheses by CAD/CAM is advantageous, since a highly skilled technician is not required to sculpt a wax ear. The whole process is undertaken solely on the computer, and the patient can see the result on the screen before the ear is fabricated. In addition, the digital image and silicone mould can be preserved. The latter is durable and permits multiple pourings. This is important, since a replacement is usually required every two years because of discoloration of the pigments in silicone elastomer. [26]

LABORATORY PROCEDURES

Computer-Aided Designing/Computer-Aided Manufacturing (CAD/CAM)

Owing to the increased demand for safe and esthetically pleasing dental materials, new high-strength ceramic materials have been recently introduced as materials for dental devices. Since these materials have proved to be inimical to conventional dental processing technology, new sophisticated processing technologies and systems have been anticipated for introduction into dentistry. One solution to this is the introduction of computer-aided design and computer-aided manufacturing (CAD/CAM) technology. In dentistry, the major developments of dental CAD/CAM systems occurred in the 1980s.

There were three pioneers in particular who contributed to the development of the current dental CAD/CAM systems. Dr. Duret was the first in the field of dental CAD/CAM development. From 1971 he began to fabricate crowns with the functional shape of the occlusal surface. He then developed the Sopha System, which had an impact on the later development of dental CAD/CAM systems in the world. The second is Dr. Moermann, the developer of the CEREC system. He attempted to use new technology in a dental office clinically at the chairside of patients. The emergence of this system was really innovative because it allowed same-day ceramic restorations. When this system was announced, it rapidly spread the term CAD/CAM to the dental profession. The third is Dr. Andersson, the developer of the Procera system. At the beginning of the 1980s, he attempted to fabricate titanium copings by spark erosion and introduced CAD/CAM technology into the process of composite veneered restorations. This was the application of CAD/CAM in a specialized procedure as part of a total processing system. This system later developed as a processing center networked with satellite digitizers around the world. Such networked production systems are currently being introduced by a number of companies worldwide. [20]

All CAD/CAM systems consist of three components:

1. A digitization tool/scanner that transforms geometry into digital data that can be processed by the computer.
2. Software that processes data and, depending on the application, produces a data set for the product to be fabricated.
3. A production technology that transforms the data set into the desired product.

The Digitization Process

Most of the current commercial CAD/CAM systems available for the fabrication of crowns and FPDs use a stone model as their starting point. The surface of a stone model is measured using various measuring tools to obtain the digital data that represent the morphology of the target tooth. These measuring tools are called digitizers and scanners. A variety of methods of digitizing have been investigated and developed. The methods currently available for practical use are a contact probe, a laser displacement gauge and a line laser beam with a CCD camera[20] and optical scanners.[27]

The CAD process

Three-dimensional data are produced on the basis of the master die. These data are processed by means of specialized dental design software. After the CAD-process the data is sent to a special milling device that produces the real geometry of the object[28].

The data of the construction can be stored in various data formats. The basis therefore is often standard triangle language (STL) data. The CAD software can be used to design copings and bridge frameworks, crowns and bridges, inlays/onlays/veneers, customized implant abutments, implant bridges and bars, surgical implant placement guides and provide virtual diagnostic wax-ups. RPD frameworks can also be designed with CAD.

The CAM process

The actual coping or framework can be fabricated via two methods (Figure 5):

- Subtractive manufacturing
- Additive manufacturing

Subtractive manufacturing[27]:

The construction data produced with the CAD software are converted into milling strips for the CAM-processing and finally loaded into the milling device. Processing devices are distinguished by means of the number of milling axes:

1. 3-axis devices
2. 4-axis devices
3. 5-axis devices

Additive manufacturing[29]:

Subtractive methods have some limitations in comparison with additive techniques. Rapid prototyping (RP) techniques, the so-called “generative manufacturing techniques”, exhibit the potential to overcome the described shortages. RP simply consists of two phases: virtual phase (modelling and simulating) and physical phase (fabrication). The chief benefit of RP techniques is models that can be produced with undercuts, voids, intricate internal geometrical details and anatomical landmarks.

Classification of RP technologies in dentistry[29]:

1. Stereolithography
2. Inkjet-based system
3. Selective laser sintering
4. Fused deposition modeling

A few advantages of using CAD/CAM technology are[28]:

1. Applications of new materials – high strength ceramics that are expected to be the new materials for FPD frameworks have been difficult to process using conventional dental laboratory technologies.
2. Time effectiveness.
3. Reduced labour.
4. Quality control.
5. Scanning an image and viewing it on a computer screen allows the dentist to review the preparation and impression, and make immediate adjustments to the preparation and/or remake the impression if necessary.
6. By using CAD/CAM zirconium implant abutments, light transmission into the gingival sulcus is allowed, thus preventing the grey of opaque metal parts from showing through peri-implant tissue.
7. Latest innovation in CAD/CAM systems allows occlusion to be viewed and developed in a dynamic state.

The application of dental CAD/CAM systems is promising, not only in the field of crowns and FPDs, but also in other fields of dentistry. There is no doubt that the application of CAD/CAM technology in dentistry provides innovative, state-of-the-art dental service, and contributes to the health and Quality of Life (QOL) of people.

Virtual Articulators

Innovative research in the field of Virtual Reality (VR) has found applications in the field of prosthodontics with several articulator designs which are used for fabrication of restorations compatible with the stomatognathic system. The transition from numerous mechanical articulator designs to recently developed virtual articulators is a major breakthrough in the development of the articulator design[30].

Virtual articulators are also called as “software articulators” as they are not concrete but exist only as a computer program. They comprise of virtual condylar and incisal guide planes. Guide planes can be measured precisely using jaw motion analysers or average values are set in the program like average value articulator.[30]

1. The virtual articulators are able to design prostheses kinematically.

2. They are capable of simulating human mandibular movements, by moving digitalized occlusal surfaces against each other.

3. They enable correction of digitalized occlusal surfaces to produce smooth and collision-free movements.

The virtual articulator is a precise software tool that deals with the functional aspects of occlusion along with CAD/CAM systems substituting mechanical articulators and thus avoiding their errors.[30]

FUTURE PROSPECTS

Continued research is required for better dental productivity. Research in areas like optical coherence tomography (D4D Technologies) would allow creating a sliced image of the tooth or other structures. It could be used for potential caries diagnosis, tooth crack location, CAD/CAM imaging, subgingival margin location, periodontal diagnosis, soft tissue analysis, and more[9]. Upcoming 3D printing technology (RepRap, MakerBot, Robo 3D) and advancements in lasers (Fidelis plus III Er:YAG laser) and nano-optics also show promise. The time isn't far when the clinician or dental assistant will be controlling procedures via a computer while a robotic system performs the actual procedure.

CONCLUSION:

Advances in digital imaging, computer aided design, internet communication, digital manufacturing and new materials have undoubtedly simplified the diagnostic process and improved treatment outcomes. In clinical practice, digital technology has impact over patient motivation, practice management and clinical treatment procedures. Imaging techniques like RVG and CBCT help to visualize the anatomic structures in a more detailed and precise way. Digital impression systems enable accurate and fast recording of impressions which are immediately stored as data. Occlusion analyzers help to evaluate the occlusion and diagnose occlusal problems, which is not possible with conventional techniques. On the laboratory side, digital technology has greatly enhanced the accuracy and decreased the time and cumbersome procedures required to produce quality restorations and prostheses. Using CAD/CAM systems, the clinician can upload data (impressions, prepared tooth virtual models, case photographs) directly to the lab technician, who can then provide suggestions and the treatment can be altered accordingly. It is beneficial for the lab technicians too as it enables them to conceptualize the prosthesis better and have an idea beforehand. If used well, these digital advancements can redefine the way dentistry is practiced and help to provide better treatment results, thereby achieving the utmost for the profession.

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FIGURES:

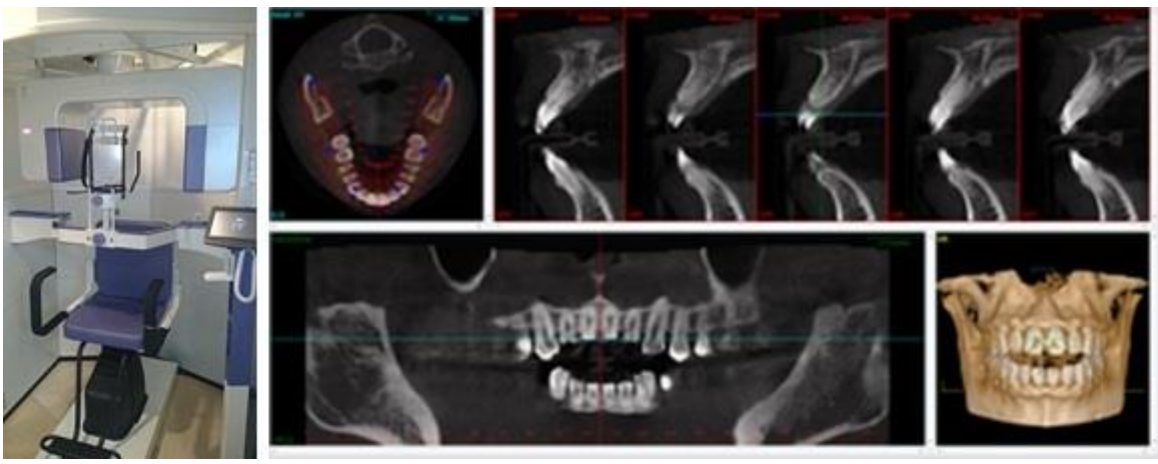

FIGURE 1: : A CBCT scanner; The scanner collects data and reconstructs it, producing what is termed a digital volume composed of 3-D voxels of anatomical data that can then be manipulated and visualized.

FIGURE 2: A digital impression system consisting of an intraoral scanner connected to a workstation with a computer display; A virtual model is obtained through the scan on which a prosthesis can be designed.

FIGURE 3 :The CEREC 3 system (Sirona) can fabricate inlays, onlays, crowns and the cores/frameworks of fixed dental prostheses.

FIGURE 4: A guide template for precise implant placement designed using specialized implant planning software and fabricated using stereolithography.

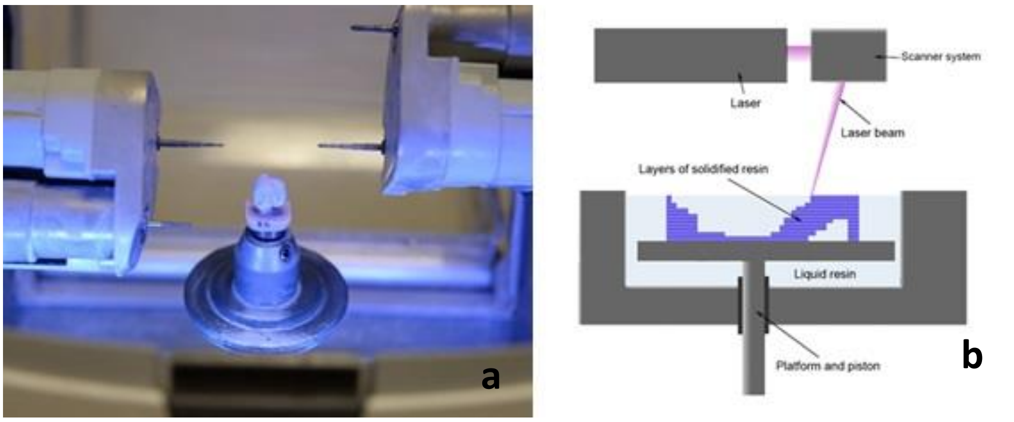

FIGURE 5: Subtractive manufacturing by milling (a) and additive manufacturing by stereolithography (b).