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Review Article

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Digital Revolution in Dentistry

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Abstract

Digital dentistry is defined as the use of advanced technology for dental devices, which incorporates digitalized computer controlled devices to perform all dental treatments in a possible better way rather than electrical or mechanical tools. The new era of technology becomes the best supporting devices involved everywhere and dentistry is no exception. It is an advancing field which keeps changing continuously and helps the human efforts, skills to be utilized in a proper way for better outcome of results. The digital revolution in dentistry started by the French professor Duret, who invented CAD/CAM in 1973. He has become the godfather of digital dentistry. The right path started with the invention of CAD/CAM and then leading to advancing digital devices in every aspect of dental treatment includes CBCT with lesser radiation, intra-oral and extra-oral scanners, dental soft ware's, 3D printers, digital Impressions.

Keywords: Digital Dentistry; CAD/CAM; Artificial Intelligence

Introduction

In this new era, computers and technological advanced devices becomes an integral part of the dental procedures. This smarter device helps in each and every aspect. In dentistry it started from case history, clinical examination, and radiographic evaluation of 2D x-ray. Today, digital dentistry revolutionized the treatment comprises from case record maintenance to each and every treatment procedure. The most important revolutionized digital technique includes:

- CAD/CAM
- Digital Imaging
- Intra-oral camera
- 3-D printing
- Computer assisted/ guided surgery
- Diagnodent
- Magnification
- Artificial intelligence.

CAD/CAM (Computer aided designing/computer aided manufacturing)

Nowadays practicing dentistry in a digital way is revolutionizing the every step of processing and fabricating prosthesis, restoration in a better way. This made the laboratory procedure very simple and accurate. The advanced technology with the computers makes all restoration procedures into individual parts effectively. CAD/CAM is becoming popular and easily available which is having access to most of the dental laboratory and production centers, which will pave the way for effective dental practice.

In dentistry CAD/CAM generating numerous advantages such as ease of access, defect less, accurate prefabricated material in an controlled manner, excellent reproducibility and storage of data in a standardized technique. It is possible to implement every step of prosthesis producing with precision and efficiency.

Definition: CAD/CAM in dentistry called as synonym for Prosthesis made by milling technology. CAD is the Computer- Aided Design and CAM is for Computer-Aided Manufacturing. It does provide

information on designing and automatic fabrication of prosthesis [1].

Components

1. A digitalized tool/ scanner
2. Software
3. Production technology.

Production concepts in dentistry: Depends in location of components of CAD/CAM system. Three units include

1. Chair side production
2. Laboratory production
3. Centralized fabrication in production center.

Chair side production

This method involves restorations are fabricated at chair side without the involvement of any laboratory procedure. This is possible with the use of intra-oral camera that replaces conventional impressions and processing steps in every clinical situation to gain precise details of dental structure without wasting time. The fabrication step is direct and finished in single appointment. CEREC system currently offers this step to produce chair side fabrication without any difficulty. CEREC system comprises of various material with water cooling from glass ceramic to high performance oxide ceramic.

It has success rate of 90% for inlays over 10 years and 85% after 12-16 years. This is the first system for CAD/CAM in dentistry and third generation of product. Due to 3-D reconstruction of occlusal surfaces with every minute details recorded, makes it unique amongst all.

Laboratory production

In this method, clinician first send the recorded impression to dental lab and then master cast is fabricated in the lab. After the preparation of master cast, the casting procedure is done completely in the dental laboratory by the 3-D data produced with the information based on master cast. With the help of specially designed software the data is processed and information given to milling devices that create real prosthetic geometry in the dental laboratory. Final step includes trial fit of the frame is checked in the cast and if any correction is necessary, it is made on the master cast.

Centralized production

In this type, the step involves the use of advanced scanners in the dental lab which is connected with the production centre through internet. From the scanner information gathered in the lab are sent to production centres, then accurate restoration are fabricated by CAD/CAM device. Then final step involves sending the prepared prosthesis to the concerned lab. The first two steps involved in the dental lab, while the third step takes place in production center. But at the end, procedure will be in the hands of technician. Even though with advanced technology it is necessary to have skilled technician in the dental lab. Recently there is possible way in which impression can be sent directly to production Center and fabrication is more accurate.

CAD/CAM components

1. Scanner
   - Optical scanner
   - Mechanical scanner
2. Software designing: The design and manufacturing of various types of dental prosthesis and restoration is made possible with the help of specially designed software system and it allows the data for fabrication of crown, FPD. The basic software language therefore called as Standardized Transformation Language (STL) data.
3. Processing devices: These are distinguished by the number of milling axis devices such as 3-axis device, 4-axis device and 5-axis device.
4. Milling devices: Two types of milling variants are available; they are dry processing and wet milling.

Materials used in CAD/CAM processing

1. Resin material
2. Metals
3. Infiltration ceramics
4. Silica based ceramics
5. Oxide based high performance ceramic.

Processing stages: Three steps are described in CAD/CAM processing steps based on dentistry are:

1. Green stage processing
2. White stage processing
3. Processing in hot isostatic condition.

Significance to dentistry

The use of advanced CAD/CAM technology in recent years strongly influenced dentistry for technical production of prosthesis in every step makes it most suitable for clinician, technician and patient. The significance of CAD/CAM due to production of material in dentistry by ease of access to ceramic materials with extreme durability. The value added stability of Zirconium oxide ceramic with longer success rate makes it most indicated for many years, which is an alternative to metal for permanent restoration and prosthesis [2,3].

Advantages

1. Simplicity
2. No classical Impression and laboratory procedure needed
3. Rapid fabrication
4. Saves time.

Disadvantages

1. Comparatively costly due to use of CEREC apparatus
2. Technique sensitive.

Conclusion

CAD/CAM system provides fully automated fabrication technique in a very short time with standardized quality of dental prosthesis. Also, the nature of technique is more accurate and reduces the possibility of cross infection during impression and fabrication steps. The use of biocompatible high strength material results in excellent esthetic and accurate fitting of restorations and prosthesis.

3-D printing technology in dentistry

3-D printing developed in 1980's which gained popularity in modern dentistry as it provides comfort and better quality of restoration in every aspect. The restoration made by 3-D printing technology is very fast and accurately adaptive when compared to restorations conventionally produced by the lab technicians. History of 3-D printing involved in the year 1983 by Charles Hull. He used an excellent technique called stereo lithography which will make an exact replica of 3D and virtual models. This gained more popularity across the world in different disciplines which needs minute millimetric like précised aeronautics and architecture of medicine [9].

In dentistry, there are various technologies in 3-D printing includes:

1. Selective laser melting: This is highly useful in casting alloys. In this technique, there is a layer by layer deposition of powder material one above the other using heat by computer controlled laser radiation.
2. Stereo lithography: This is the most popular in 3-D technology. It uses photosensitive monomer resin that polymerizes and solidifies on exposure to UV-light at surface and reproduces the structures as original model.
3. Fuse deposition modeling: This technique uses a computerized model of scan. After scanning, it produces melted thermoplastic polycarbonate in layered fashion from bottom to top.
4. Digital laser processing: It uses projector light source which cures liquid resin layer by layer in upside down fashion from which residual liquid drains off.

Applications

- In oral surgery, it allows replication of anatomic structures like skull to micro complex structures before surgery. This allows both visual of touch interactions and might reduce risks during surgeries like bone augmentation procedures.
- In implantology, it provides guidelines of surgical procedure to insert implant. These can print biometric scaffolds for bone cell enhancement of tissue growth and development.
- In maxillofacial prosthesis, it can be made more accurate by scanning manual counterpart of duplications.
- In prosthodontics, custom trays can be made by scanning impression or direct prototype can be scanned and used directly.
- Computer-guided surgery involves the use of prefabricated models and surgical guides fabricated to replicate the exact anatomy of oral and dental structures which assists in surgical procedures, root canal procedures, implant placement, and makes the clinician to perform in a better way.

In all, the 3-D printing has an upper hand to CAD/CAM because of its high quality resolution with quick ease of fabrication, but still it has few drawbacks such as ages of being inexpensive, skin irritants causing inflammation, having limited shelf life and being non-sterilizable. So, these materials will replace most of the classical techniques but needs much improvement to replace classical techniques completely.

Diagnodent

In dentistry the fundamental for treating the patients is diagnosing dental caries in most of the cases. Diagnodent is a laser fluorescence device for detecting caries. It is extremely accurate and reliable adjunct for detection of sub surface caries, which saves extensive restoration and tooth loss. It is a pen like probe which simply glides over the tooth and it alarms the operator when there is sign of hidden caries [4]. Scanning the teeth with diagnodent allows dentist to detect caries as early as possible, improving treatment options and providing patients with optimal health care. Diagnodent works on the principle that fluorescence is the phenomenon when light at one wavelength is absorbed by the tissues and second wavelength emitted by the tissues. Naturally enamel, dentin has certain fluorescence called auto fluorescence which attributed to some chromophores in teeth. Red light as well as infrared fluorescence is less absorbed and scattered by enamel than light of short wavelength, making it possible to measure fluorescence from underlying dentin. Red light induced fluorescence can be used to distinguish between sound and carious tooth structure. The difference between fluorescence capacities can be recorded and observed for any carious lesion. It comprises of three stages of detecting dental decay includes stage 1 (0 to 14) no caries, stage 2 (15 to 20) histological caries confined within enamel, stage 3 (21 to 99) histological dentinal caries. In modern dentistry caries detection devices plays a major role in treating patients, this laser fluorescence device plays a valuable tool in detection of early caries amongst advanced caries detecting devices.

Lasers in dentistry

In last decades, a lot of research has led to develop dental lasers of many types that can be used in dental procedures varying from pulpal diagnosis, canal disinfection and retreatment to root resection and other surgical procedures. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation. Photons are the basic unit of light. When light protons are released and energy is emitted as a coherent wave, this energizes the neighboring

atoms, emitting additional photons resulting in amplification and producing a laser beam. Generation of the laser beam requires active medium which can be solid, liquid or gas contained in tube. When current is applied, a stimulated emission of radiations states and when energized atoms became more in number than atoms of ground state, population inversion occurs. Those photons can be directed with help of mirror and delivered to the target area [14,15].

Laser beam has different characteristics, they are Monochromatic, Collimated, Coherent and intense.

In dentistry there are 2 types of laser delivery available systems, they are Hollow tube delivery system and Glass fibre optic system.

Types of Lasers commonly used in dentistry

1. Nd-YAG-2100 nm
2. Diode-810 and 940 nm
3. Er: YAG-2940 nm
4. Er.Cr: YSGG-2790 nm
5. Argon-400 - 514 nm
6. CO_2-10,600 nm.

Applications of laser in dentistry

1. Vitality testing
2. Dentin Hypersensitivity
3. Depigmentation
4. Pulp capping and Pulpotomy
5. Disinfection of root canal
6. Biostimulation

Figure 1: Diode Laser.

Figure 2: Er: YAG Laser.

1. Dental surgeries
   - Biopsy
   - Gingivectomy
   - Frenectomy
   - Crown lengthening
   - Incision and drainage
   - Enucleation.

Lasers are advanced digital tool for management and treatment of certain disease and condition with less pain and postoperative complications.

Imaging revolution in dentistry

In imaging field of dentistry, radiographs are very important especially for diagnostic purpose. Radiographic images do not replicate the accurate anatomic structures. Radiograph does not reveal the soft tissue to hard tissue relations. Due to disadvantages of 2-D imaging technique, advanced 3-D imaging modalities, revealing additional information in dentistry like Cone Beam Computed Tomography (CBCT), Magnetic Resonance Index (MRI) and Ultra Sound (US) has introduced. In 1895 William Roentgen accidently discovered an image from cathode rays. In 1896 Dr. Otto Walkhoff first took images in medicines field. Imaging technique in dentistry is broadly categorized into intra-oral and extra-oral digital dialogue, Ionizing and non-ionizing, 2D and 3D imaging.

2-D imaging is a good radiographic imaging for most dental treatment such as caries detection, periodontal and periapical condition of dental structures. Even though there is limitation of lack of 3-D images. 3-D imaging has grown very fast in all fields and medical sciences.

Digital radiographs

RadioVisioGraphs

This is the first system in the digital radiograph invented by Trophy in France (1987). It runs by capturing radiograph using sensor.

Digital radiograph are of 3 types in currently available system such as

1. Direct:
   - CCD- Charged Coupled Devices.
   - CMOS- Complementary Metal Oxide Semiconductors.
2. Indirect:
   - PSP- Photo Stimulable Phosphor

Advantages

1. Short Processing time.
2. Quick View Image.
3. Lesser radiation about 80% reductions compared to conventional radiograph.
4. No need of darkroom processing.
5. Cephalometric radiograph used in dentistry to compare changes in dental and skeletal structures in orthodontic treatment including soft tissues with lesser radiation dose.

Cone beam computed tomography

In 1972 Sir Godfrey N. Hounsefield developed the first commercial Computed Tomography system. Concept of CBCT is based on cone shaped x-ray beam contacted on a 2- Dimensional detector. This rotates around the object and produces sliced 2-D image reconstructed in to 3-D using modified original cone beam algorithm developed by Aboudara., *et al.* in 1984.


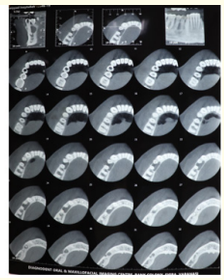

Figure 3: RadioVisioGraphy attached to computer.

Figure 4: CBCT Image-Axial view.

CBCT Acquisition comprises of four components.

1. X-ray generation
2. Image detector system
3. Image reconstruction
4. Image display.

It is used mostly for diagnosing dental and osseous disease in TMJ and jaws. CBCT is classified based on site of view into large, medium and limited volume units. Most commonly limited value CBCT is used in dentistry due to more accuracy level [11,13].

Applications

1. In periodontics for detecting fenestration, dehiscence, furcation defects.
2. In orthodontics, detecting dental and skeletal relationship, impacted teeth, arrangement of teeth in 3-D view of cleft lip and palate patients.
3. In oral and maxillofacial surgery for diagnosing cyst, tumor, orthognathic defects, fracture and bony relations.
4. In implantology, preoperative and postoperative assessment of bone and implant.
5. In Endodontics for detecting abnormal anatomy of tooth, periapical lesion, diagnosing cyst from granulomas, root fractures and canal configurations [17].

Limitations

1. Patient and beam related artifact
2. Large noise
3. Poor soft tissue relation whish is very difficult to acquire.
4. Large setup of instruments.

Magnetic resonance imaging

First MRI introduced by Paul Lauterbur in the year 1973. MRI was developed for clinical purpose in the year 1980. This procedure involves patient is kept inside the large magnet which produces magnetic resonance imaging. The nuclei of many atoms of body, particularly hydrogen, to align the magnetic field are the method for image acquisition. After that radiofrequency plate is used in which the nuclei absorbs as energy. Then MRI is constructed by using these signals. Recently to visualize the dental tissues, the new technology of imaging called "sleep Imaging" is used to get most benefited images.

Applications

1. Soft tissue imaging.
2. Malignancy of lymph nodes.
3. Neoplastic involvement of perineurium.
4. TMJ and Disc Position.

Disadvantages

1. Needs longer time for scanning.
2. High Cost.

UltraSound

Sonography is a technique based on sound waves that acquires in real time and without use of ionizing radiation. In dentistry ultrasound first reported by Baum., *et al.* in 1963.

Applications

1. To identify stone in salivary gland and duct
2. Vessels of neck
3. Lymph nodes evaluation
4. Neoplasia in neck and head region.

Disadvantages

1. Depends on Operator.
2. Technique Sensitive.
3. Limited applications in head and neck because sound waves are mostly absorbed by bone.

Artificial intelligence (AI)

The Artificial Intelligence is called as intelligence of the machines which in contrast to natural human intelligence and makes every action successful to the maximum. The future technology of entire world will be mostly depends upon AI. In dentistry there is a possibility that new era will start with AI in every branch starting from data collection of patient records to final treatment. Nowadays use of AI in dentistry includes radiological diagnosis, treatment plan by gathering information in every aspects of digital imaging devices. In orthodontics smile designing is popular with the help of AI [5,6]. It has major role in endodontics and prosthodontics by creating precise 3-D models, surgical guides which enhance the accuracy of treatment. In future, the impact of AI in dentistry will result in better comfortness to the human society.

Magnification

In dentistry the human naked eye not able see all what we are treating. So, it is necessary to see even more minute details with the help of magnification devices, which will increase the precision of treatment and better outcome. Magnification devices in dentistry are of three basic types such as Dental Loupes, Procedure scope, Dental Operating Microscope [13]. Loupes also called as telescope

used in dentistry with magnification range of 2-5X zoom. It is convenient to use in all procedures but ergonomics and magnification range is less compared dental microscope. In 1981 Apotheker introduced first microscope in clinical procedures. When compared to human eye microscope provides 100 times the information with 10X magnification. The range of magnification is from 2X to 20X zoom. There are three types of magnification range such as low, medium, higher magnification. When the magnification range increases the field of view and depth decreases. The parts of microscope include eyepiece, binoculars, magnification changers, objective lens, illumination with light source and accessories. The use of microscope in endodontics include locating extra canals, locating canal orifices, locating fractures, negotiation of calcified canals, removing separated instruments, retreatment and in surgical endodontic procedures. Using magnification in dentistry is more important to achieve excellent precision and better ergonomics, but the main disadvantage is time taking procedure and high cost.

Figure 5: Dental operating microscope.

Figure 6: Dental Loupe with 3.5X magnification.

Conclusion

This chapter covers the important digital devices which possibly helps the clinicians to perform better and makes the patient care more satisfying. The conventional techniques and devices used previously mainly depends on the clinical skill and experience of the operators. Nowadays these advanced devices in dentistry supports the operator skill in everyday work and resulted in increased quality, productivity, accuracy and becoming inseparable technological tool in dentistry.

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