© 2018 IJSRSET | Volume 4 | Issue 8 | Print ISSN: 2395-1990 | Online ISSN : 2394-4099
Themed Section : Engineering and Technology

Latest trends in Digital Dentistry : A Review

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ABSTRACT

CAD/CAM dental restoration is available as Chairside and Labside. There has been lot of developments in dental materials and computer software technology which leads to the success of CAD/CAM technology. Dental restoration can be done by two methods, both having its own advantages and limitations namely Conventional Dental Restoration, Digital (CAD/CAM) Dental Restoration. A number of CAD-CAM systems are developed for electronically designing and milling dental restorations. These systems lead to elimination in the need for impressions, temporary prostheses, and laboratory assistance. Computer Aided Design (CAD) involves use of Computers for creating projects with high accuracy. Computer aided manufacturing (CAM) process has been developed to materialize virtual objects using CAD. Virtual file can be converted into a real object using Computer Aided Manufacturing (CAM) which operates by a machine connected to a computer. This paper gives a brief knowledge about the uses of CAD/CAM technology in the field of dentistry such as fabrication of crowns, restoration. Developments in digital dentistry lead to better patient experience and improve the productivity and economics of the dental practice.

Keywords : Restoration, fixed partial dental restoration, CAD/CAM, Digital Dental Restoration, Intra Oral Scanner, Ceramics.

I. INTRODUCTION

Two most common oral diseases in dentistry are tooth decay and the periodontal disease like gum disease or pyorrhea. The restoration of teeth, extraction or surgical removal of teeth, scaling and root canal treatment are most common treatments. Dental restoration is a process of protecting the damaged tooth from further damage using dental restorative material. This helps to restore the function and morphology of missing tooth structure. The replacement of missing tooth structure that is supported by dental implants is also known as Dental Restoration.

II. DENTAL RESTORATION

Dental restorations can be divided into two broad types: 1) Direct restorations and 2) Indirect restorations.

When a soft or malleable filling is placed into a prepared tooth cavity immediately, it is known as Direct tooth restoration. The material is then set hard till the tooth is restored. Direct restorations usually set quickly hence they are advantageous. But this type of restoration has less strength and not suitable especially where filling become larger. This procedure requires single clinical visit. Based on the type and location of the filling dentists choose the filling. For example, for replacements near the tooth root or

other areas which are not subjected to heavy pressure from chewing, glass or resin, ionomers are often used.

Indirect tooth restoration involves tooth replacements in the form of crowns, inlays, onlays, bridges, dentures, where restorations are fabricated outside the mouth using the dental impressions of the tooth. The finished restoration is usually bonded permanently with dental cement. More than one clinical visit is required in case of an indirect tooth restoration as the fabrication of restoration takes time. Variety of materials like metal, ceramics, composites etc. can be used for making restoration.

III. METHODS OF DENTAL RESTORATIONS

There are two methods of dental restoration: Conventional Dental Restoration and Digital (CAD/CAM) Dental Restoration. Conventional Dental Restoration process is used from many decades in the dental field. Dental restoration is the process of replacement of the missing tooth structure with various types of restoration like crowns, inlays, onlays, etc. to restore the same function. Conventional Dental Restoration process mainly consists of following four processes: 1) Tooth preparation 2) Taking the impression 3) Temporary crown placement and 4) Fabrication of dental restoration. There are certain limitations of Conventional method: 1. Dental impression in conventional method is not accurate and precise due to which the dental mold is not prepared properly and error occurs in final restoration. 2. Metals are used for the restoration purpose using casting which is aesthetically not acceptable. 3. Predictability of outcome is negligible. 4. Time taken for complete restoration process is very long. To overcome all these limitations, Digital Dental Restoration an upcoming technique, is suggested. Digital Dentistry is vastly developing in dental restoration field under the name CAD/CAM (computer-aided design/computer-aided manufacturing) Dentistry. The term 'CAD/CAM' in dental technology is basically a synonym for prostheses produced by 'milling technology'. The CAD/CAM technology in dental field was introduced in 1970s (Klim). In the present world everyone prefers to do the treatment in minimum time. In dentistry CAD/CAM technology had made this possible with greater speed and accuracy. CAD/CAM gives new wing to dental field through which patient's get relief from the inconvenience of conventional dental restoration and offers better aesthetic restorations in not more than two visits.

IV. CAD/CAM RESTORATION STEPS

CAD/CAM restoration involves three steps, first being image acquisition in which dentist scans the dental arch by using intraoral scanner. Generated 3D image is divided into number of facets (triangle). The intraoral scanners are the optical scanners that record images of the dental arch with greater accuracy and speed. It reduces steps and overall time of restoration. The next step is Design which will be performed with Computer Aided Design (CAD). With the help of CAD different types of designs can be carried out such as copings and fixed partial denture (FPD) frameworks, full anatomical crowns and FPD, inlays, onlays, veneers, etc. It increases the productivity, quality of design and reduces the time. Manufacturing is the last phase of the digital dental restoration process which is defined as Computer Aided Manufacturing (CAM). It consists of manufacturing the restoration from the CAD model into a physical part which may further undergo processing, finishing, and polishing before restoration into the patient's oral cavity (Duret et al., 1988).

During the conventional dental restoration process, most of the time impression taken is not accurate and sometimes the proper dental impression is not achieved in first attempt so repetitions are required which consumes time of patient. Also patients have to bear the smell of impression material which feels them uncomfortable during the whole process. Thus to eliminate this problems, intraoral scanners are

introduced which take the digital impression of teeth in less time with better accuracy and precision.

V. CAD/CAM PRODUCTION TYPES

There are two different production types based on the location of the components of the CAD/CAM systems, in dentistry: **Chairside production:** Fabrication of dental restorations can take place at chairside without a laboratory procedure. The conventional impression technique is replaced by digitalisation instrument intra-oral camera, in most clinical situations. This saves lot of time and restoration can be done only in a single appointment. **Laboratory production:** This type of production is similar to the traditional working between the dentist and the laboratory. A master cast is fabricated first as soon as the dentist sends the impression to the lab. The remaining CAD/CAM production steps are carried out completely in the laboratory. Three-dimensional data is produced with the help of a scanner, on the basis of the master die. Suitable CAD software is used for further processing. 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 is inspected and if there is any correction, it will be corrected on the basis of the master cast (Beuer et al. 2008). For selection of procedure to be followed, consideration should be given to esthetic demands, chairside time, and laboratory costs, number of visits and convenience and return on investment associated with CAD/CAM equipment (Prajapati et al. 2014).

VI. MATERIALS FOR PRODUCTION OF CROWNS

Several materials are used for production of crowns, inlays, onlays. These are produced using Milling machines. Some of the materials are: Metals (Titanium, titanium alloys, chrome cobalt alloys): The milling of precious metal alloys are not of interest, due to the high metal attrition and the high material costs.; Resin materials: For long-term provisional or for full anatomical long term temporary prostheses it is possible to use resin materials directly as crown and FPD frameworks; Silica based ceramics: Grindable silica based ceramic blocks are offered by several CAD/CAM systems for the production of inlays, onlays, veneers, partial crowns and full crowns; Oxide high performance ceramics : Al_2O_3 :Aluminium oxide is used in the case of crown copings in the anterior and posterior area, primary crowns and three-unit anterior FPD frameworks; Yttrium stabilised zirconium oxide ZrO_2 Y-TZP: Zirconium dioxide is a high-performance oxide ceramic with excellent mechanical characteristics. It has high flexural strength and fracture toughness compared with other dental ceramics. This leads to use of this material as framework material for crowns and FPDs, and, in appropriate indications, for individual implant abutments. The addition of three molecules of Y_2O_3 results in a stabilising tetragonal phase at room temperature (Beuer et al., 2008).

Various CAD/CAM technologies are developed for deposition of materials. One of the technique is the evolution of a computer-aided design/computer-aided manufacturing (CAD/CAM) process where ceramic paste is deposited in a layer-by-layer sequence (robocasting). This was done using a CNC machine to build up core and fixed partial denture (FPD) structures. Al_2O_3 or ZrO_2 are blended into a 0.8% aqueous solution of ammonium polyacrylate in a ratio of approximately 1:1 solid: liquid. A viscosifying agent, hydroxypropyl methylcellulose, is added to a concentration of 1% in the liquid phase, and then a counter polyelectrolyte is added to gel the slurry. There are two methods for robocasting crown structures (cores or FPD framework): First method consists of the core to be printed using zirconia ink without support materials. The stereolithography (STL) file generated is inverted (occlusal surface resting on a flat substrate) and built. The second method uses a fugitive material composed of carbon black and ceramic material. During the sintering

process, the carbon black is removed (Silva et al., 2011).

Dental biomaterials are used on large scale in all areas of routine dental practice. There are mainly two methods for their application. First method consists of placement of dental biomaterials into living tissues, such as teeth, to fill the space. Second method involves use of dental devices such as crown and bridge restorations and dentures. These are fabricated using various materials to restore the morphology and function of the dentition. Crown and bridge restorations are one of the main treatment methods used by general practitioners. There is also a greater demand for all-ceramic restorations. Development of new materials such as highly sintered glass, polycrystalline alumina, zirconia based materials and adhesive monomers, will provide great assistance to dentists to meet this demand (Miyazaki et al., 2009).

VII. RESTORATION USING CAD/CAM COMPONENTS AND VARIOUS TECHNIQUES

A digital data is captured directly from the patient mouth. With this process the model making phase is avoided. Consequently, this digitization technique is also referred to as digital impression (Miyazaki et al., 2009). For electronically designing and milling dental restorations a number of CAD-CAM systems are being generated. Such systems eliminate the need for impressions, temporary prostheses, and laboratory assistance. Furthermore, the entire procedure is completed in one appointment. There is very less information available about this new system. It is observed that this new CAD-CAM device is capable of fabricating a ceramic restoration in less than 20 minutes (Leinfelder, 1989). CAD/CAM technology was developed to solve three challenges. The first challenge consists of ensuring that especially the posterior teeth have adequate strength of the restoration. The second challenge was to create restorations with a natural appearance. The third challenge was to make tooth restoration easier, faster, and more accurate. In some cases, CAD/CAM technology provides patients with same-day restoration (Davidowitz et al., 2011).

For taking digital impressions 3D intraoral scanner with software integration has to be designed. The main purpose is to gain high speed and accuracy. The main parts of the system are Intra-Oral Scanning (IOS) hardware, CPU and display monitor. The IOS hardware is designed using non-contact optical technologies. This is based on the principle of confocal laser scanner microscopy resulting in high speed scanning. The light intensity is detected by photo-detection device, transforming the light signal into an electrical one which is recorded by a computer and can be reconstructed. The software is designed using merging of active triangulation method, surface reconstruction and Image processing tools. This results in high accurate 3D image of oral cavity, which will be displayed on the monitor screen (Seok et al., 2015). The accuracy of digital impressions obtained from various digital impression systems needs to be studied. The results of this study would provide a great help for the clinician to select an appropriate Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) scanner for digital impressions. Furthermore, the results carry implications of whether digital impressions are accurate enough to be used as an alternative to conventional impression techniques (Ali, 2015).

For gaining accuracy detailed analysis on the present methods and techniques for scanning, designing, and fabrication of CAD/CAM generated restorations along with the new classifications of CAD/CAM technology has to be carried out. Advantages of CAD/CAM technology include digital impressions and models, and use of virtual articulators. Currently, the design software has more applications including complete dentures and removable partial denture frameworks. 5 axes milling units are used for attaining the accuracy of restoration fabrication. The 3D printing technology has been incorporated into dentistry, but

does not include ceramics and is limited to polymers. Future study involves the use of ultrasound impressions using ultrasonic waves which will replace optical impressions, which have the capability to penetrate the gingiva non-invasively without retraction cords and not be affected by fluids (Alghazzawi, 2016)

Dental CAD/CAM technology is gaining popularity because of its benefits in terms of time consuming, materials savings, standardisation of the fabrication process, and predictability of the restorations. The number of steps required for the fabrication of a restoration is less compared to traditional methods. Another benefit of CAD/CAM dentistry includes the use of new materials and data acquisition, which represents a non-destructive method of saving impressions, restorations and information that is saved in a computer and constitutes an extraordinary communication tool for evaluation. The incorporation of dental technology has not only brought a new range of manufacturing methods and material options, but also some concerns about the processes involving restorations' fit, quality, accuracy, short and long-term prognosis (Brenes et al., 2016). Even though the contributions of dental CAD/CAM systems are presently limited but they are promising not only in the field of crowns and FPDs but also in other fields of dentistry (Miyazaki et al., 2011)

Aesthetics of crown plays an important role in restoration using CAD/CAM system. Aesthetic dentistry is dedicated to imitate nature by maintaining the size, shape, colour and symmetry. Development in technology leads to metal-free ceramic materials capable of reproducing a natural appearance. So traditional materials have been replaced by them. The yttrium partially-stabilized zirconium oxide does not only have the advantage of being extremely resistant, but it is also highly translucent. It has a translucency that allows about 50% of the incident light to pass through. This characteristic is more important for providing a more natural appearance to restorations. The duration of scanning and milling procedures will depend on the size of the object, the number of objects processed and the steps selected (CAM or CAD/CAM) (Bodereau et al., 2013).

There are various techniques developed in dental restorations. A new device for scanning the dental profile and reconstructing 3D digital information of a dental model based on a layer-based imaging technique was designed. This technique is known as abrasive computer tomography (ACT). This new device was proposed for the design of custom dental restoration. ACT scanned digital information was then used for producing the fixed partial dental restoration by rapid prototyping (RP) and computer numerical control (CNC) machining methods (Lee et al., 2008). The other tests involve use of Anderson-Darling test, Levene's test and Mann-Whitney test for analysis of data. For this, the study was undertaken for 20 patients to take their impressions. Crowns were fabricated from digital scans as well as silicone impressions and the crowns were clinically evaluated before cementing. It was concluded that the crowns from intraoral scans had better marginal fits than the crowns from silicone impressions. Also it was observed that they had better interproximal contact area quality (Syrek, Andreas et al., 2010).

Some applications of the use of intraoral scanning technology are to record hard and soft tissue morphology for the fabrication of a cast partial removable dental prosthesis. An open source intraoral scanner was used to scan the hard and soft tissues to create a stereolithographic file. This STL file was subsequently imported into a CAD software program for the digital/virtual design of a partial denture framework. Computer-aided design and computer-aided manufacturing technology was then used to fabricate a resin framework. This was then trial placed to evaluate accuracy and for conventional investing and casting with a cobalt-chromium alloy. The cast framework and prosthesis were judged to be

clinically accurate in fit, stability, and retention (Kattadiyil et al. 2014). The objectives have to be decided to determine the validity and reproducibility on stereographic models and 3-dimensional digital dental models made with an intraoral scanner. For this, study was undertaken which consisted of use of ten dry human skulls. These skulls were scanned and stereolithographic and digital models were made from them. The measurements were taken by two observers four times. Arch length discrepancy and tooth size discrepancy were calculated on the basis of measurements. It was found that there were statistically significant differences in the measurements for stereolithographic as well as digital models, but were considered to be clinically insignificant. It was concluded that for measuring distances in a dentition the method of making stereolithographic and digital models made with an intraoral scanner was a valid and reproducible method (Seelbach et al., 2013).

VIII. CONCLUSION

In this article, we reviewed the current state and future perspectives of the application of digital dentistry, particularly in the field of the fabrication of crowns and FPDs restorations. Researchers have done lot of study and tried to make the restoration digital with the use of digital intraoral scanners and the use of CAD/CAM technologies in the field of dentistry.

1. The invention of various types of biomaterials in the dental field gives new wings to the dental restoration which has better strength and aesthetics.
2. Restorations done with CAD have better fit and accuracy than the conventional one.
3. With CAM technology ceramics can be milled with better precision and dimensional accuracy which eliminate the use of metals by giving better strength and aesthetic appearance.
4. Even though this technologies had more advantages over the conventional method of dental restoration, the cost associated with this is very high due to this reason most of the dentists uses the conventional method.
5. Therefore if the overall cost of this system can be reduced without affecting the end results, then dentists will be able to adopt this technology. Very few researchers have studied the strength of restoration prepared by CAM technique.
6. CAE technique needs to be developed to know the various stresses developed by tooth and to avoid the tooth failure.

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