ECRONICON OPEN ACCESS

EC DENTAL SCIENCE

Review Article

Going Digital in a Prosthodontic Clinic: Technologies and Workflow

Arati Sharma*

Department of Prosthodontics and Crown and Bridge, CODS, B. P. Koirala Institute of Health Sciences, Dharan, Nepal

***Corresponding Author:** Arati Sharma, Department of Prosthodontics and Crown and Bridge, CODS, B. P. Koirala Institute of Health Sciences, Dharan, Nepal.

Received: April 22, 2019; **Published:** June 10, 2019

Abstract

Digital revolution is changing the workflow and operating procedures in Prosthodontics. Every step from diagnosis and impression making to fabrication of prosthesis have digital replacement. Recent advances in sensor technology have markedly improved the performance of intraoral scanners. Availability of affordable three-dimensional Cone-Beam Computed Tomography systems with development of inexpensive X-ray tubes, high-quality detector systems, metal artifact reduction software have increased interest in dental Cone-Beam Computed Tomography. Indication of Cone-Beam Computed Tomography in dental implant cases may go beyond diagnostics, to designing templates for guided implant placement. Digital photography when combined with the use of appropriate software for image processing has become a valuable tool for smile designing. Currently, Computer Aided Designing software has increased applications in complete denture and partial denture framework designing. Another technology gaining much attention in recent years is additive manufacturing also known as three-dimensional printing of various dental prosthesis, surgical guides etc. Dentists have started thinking of using a "virtual patient" by integrating different file formats into a single model. This study briefly discusses recent technologies and workflow in a Prosthodontic Clinic.

Keywords: *Digital Dentistry; Prosthodontics; Implant Dentistry; Additive Manufacturing*

Introduction

The intraoral scanner, a feature of the first commercially available dental Computer Aided Designing and Computer Assisted Manufacturing system (CEREC-CAD/CAM) is considered as a key feature for the analog-to-digital change in dental treatment [1]. The processing capacity of a computer was not sufficient and the software had not been as developed at that time as at present.

At present the advancements in Prosthodontics is focused on digitalization of the workflow using the broad array of technologies [2-6]. The digital revolution is changing the workflow and operating procedures in dentistry particularly in Prosthodontics. Three-dimensional imaging based on radiographic, surface scanning, and photographic, video-graphic data sets enables the capture of diagnostic information and the design of prostheses [7-27]. Then the prosthesis can be manufactured by computer numeric control (CNC) systems that automate both additive (3D-printing) and subtractive (Milling) production schemes [28-36].

A paper has raised concern that advances in computer related technologies will result in much of the manual work being replaced in the near future by machines and digital equipment, a scenario of current jobs disappearing and employment opportunities being lost [37]. However the positive effect of technological innovation resulting from digitalization cannot be overlooked. It will result in reduction of manual workload on dentists and they will be able to concentrate on more essential things. It is expected that the change to digital technology in dentistry will enable determination of the state of occlusion that each patient should have [1].

There are many benefits of going digital in Prosthodontics like reduced working time, simplified manipulation, better workplace management (no wet processing and use of gypsum products), better documentation and clarity in communication, enhanced accuracy of diagnosis and treatment planning, improved control of the design and production of definitive prostheses, and archiving individual patient data like virtual diagnostic casts without need of extra-space [2-5]. The main clinical advantage is positive impact on the patient experience [6]. Patients feel and understand that enhanced quality of care is being provided. The advantages of a virtual environment are obvious, but the scientific validation is still pending [2].

There are four basic phases of workflow in digital dentistry. They are image acquisition, data preparation/processing, the production, and the clinical application on patients. This study discusses briefly the first three phases (Figure 1).

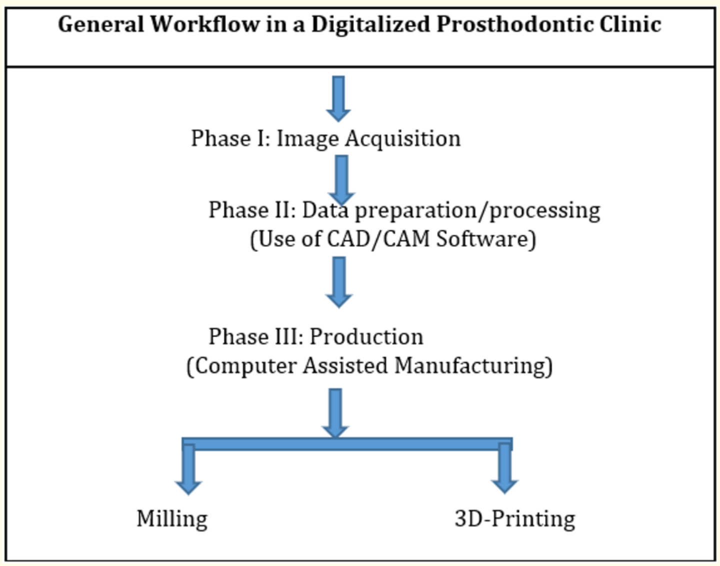

Figure 1: *Digital workflow in a Prosthodontic clinic.*

Phase I: Image acquisition

Image acquisition is the first operational phase of digital dentistry. This employs tools such as intraoral scanners (IOS) for optical impression, digital cameras for digital photography, and Cone-Beam Computed Tomography (CBCT). CBCT and optical scan technology have recently developed a lot and are profoundly changing many aspects of dentistry.

Digital impression

Digital impressions can be taken in two ways. One way is using IOS chairside to take optical impressions of dento-gingival structures. Another is lab side surface scanning.

IOS are used to capture direct optical impressions of intraoral structures. Similar to other three-dimensional (3D) scanners, they project a light source onto the structures to be scanned [1]. The images of the dento-gingival tissues captured by imaging sensors are processed by the scanning software, which generates point clouds [10]. These point clouds are then triangulated by the same software and by this 'triangulation' procedure the 3D data will be collected by the computer [1,10,28].

Lab side surface imaging or scanning includes contact and non-contact scanning of models obtained from conventional impressions. In contact scanning, a contact probe reads the anatomy of the model by following the contour of the physical structure. In non-contact scanning, laser light, optics and charged -coupled devices are used [8,9].

Recent advances in sensor technology like, miniaturization, high density, high pixel count and improvement in driving speed of electronic circuits have markedly improved the performance of intraoral scanners to be used clinically in Prosthodontics [1]. The latest-generation devices have wider indications for clinical use. Technically, IOS can be integrated in a closed system, generating proprietary files only, or can be open, producing files that can be opened using any CAD software [10]. The files captured during optical impressions may be imported into CAD software and once the restoration design is completed, the files can be transferred to computer assisted manufacturing (CAM) software and put into the milling machine [8].

Optical impressions reduce patient discomfort. IOS are time-efficient and simplify clinical procedures for the dentist, eliminating plaster models and allowing better communication with the dental technician and with patients [8-11]. However, it is not without limitations. One of the most frequent problems encountered with IOS and with optical impressions is difficulty in detecting deep marginal lines, especially in aesthetic areas where it is important to place the margins subgingival or in the case of bleeding [10]. Unlike the conventional impression materials, light cannot physically detach the gum and register non-visible areas.

Studies have shown that optical impressions are equally accurate for individual restorations or 4–5- unit bridges on natural teeth and on implants [12-15]. Though, the latest-generation scanners are characterized by very low errors in full-arch impressions [13], at present, the literature does not support using IOS for fabricating long-span restorations, such as fixed full arches supported by natural teeth or implants [16-18]. Conventional impressions are still considered as the best solution for long-span restorations.

The main digital impression systems those are available on the market include CEREC, Lava C.O.S. system, iTero, E4D, and TRIOS [38].

Cone-beam computed tomography (CBCT)

CBCT principle has been in use for almost two decades. The technique involves a single 360° scan in which the X-ray source and a reciprocating area detector synchronously move around the patient's head, stabilized with a head holder. A new generation CBCT claims to provide a more free positioning of the patient, either lying or sitting [23]. More recently affordable systems have become commercially available. Development of inexpensive X-ray tubes, high-quality detector systems like flat panel detectors, metal artifact reduction software and powerful personal computers are contributing to the increasing success of its use in dentistry [8,24-26]. Various CBCT models like hybrid or multimodal systems for combined 2D (panoramic and/or cephalometric) imaging, 3D CBCT imaging, and primary panoramic machines which are less expensive with a small detector size for scanning narrow field-of-views with a 3D button are there in the market [25].

In Prosthodontics, CBCT is generally indicated in some cases of implant therapy. Information on dento-gingival tissues obtained from optical impression can be combined and over-laid with that relating to the patient's bone structure obtained from CBCT, by using specific planning software packages [2]. Indications in implant dentistry may go beyond diagnostics. Within the processing software packages, the surgeon can design templates for guided implant placement, which are physically manufactured by milling or 3D printing and used clinically [26,27]. Implants positioned through a guided surgical procedure can be loaded immediately, using prosthetic restorations in resin, printed in 3D before the fixtures are positioned. This is known as the "full-digital" technique [3]. Today, it is possible for the surgeon to design a whole series of customized implants (root analogue implants, blade implants, maxillofacial implants) and also personalized bone grafts by importing data from CBCT into specific modelling software and then using additive manufacturing (3D printing) procedures, such as direct metal laser forming (printing of metals) [3].

Digital photography

Digital photography in Dentistry when combined with the use of appropriate software for image processing, allows to design a patient's smile virtually. This is known as digital smile design, a valuable tool in modern aesthetic and cosmetic dentistry [2].

Phase II: Data preparation/processing (Use of CAD/CAM Software)

Special Software is provided by the manufacturers for the design of various kinds of dental restorations. The Software of CAD/CAM is continuously being improved [1,28]. Currently, the design software has more applications including complete dentures and removable partial denture frameworks [29]. Generally, there are multiple standard data formats in three-dimensional CAD software. As mentioned before, the files captured during optical impressions may be imported into CAD software and once the restoration design is completed, the files can be transferred to computer assisted manufacturing (CAM) software and put into the milling machine. The CAM software automatically translates the CAD model into tool path for the CNC machine [39].

CAM software is software that generates driving data (NC data) for a processing machine. The method used for data processing depends on the type of processing apparatus, the most common method is milling. Now-a-days 3D printing is also gaining much attention. In a milling process, a ball end mill with a hemispherical tip is generally used as a processing tool. The processing method depends on how the ball end mill is applied to the milling block, and a 3-axis processing method or a 5-axis processing method is used. In 3-axis machining, the milling tool is driven by parallel movement with respect to three orthogonal axes, XYZ axes; whereas in 5-axis machining, the milling tool is driven by a total of five types of motion, XYZ translation in three orthogonal axes and rotational movement around the XY axes [39,40]. Thus, five-axis machining is used for machining complex shapes including undercuts.

Phase III: Production (Computer assisted manufacturing)

Milling (Subtractive manufacturing)

It is a type of restoration fabrication method that utilizes subtraction manufacturing technology from large solid blocks of materials. Computer numerically controlled (CNC) machining, in which power-driven machine tools are used to mechanically cut the block of material to achieve the desired geometry, all the steps being controlled by a computer program [1-5].

The milling units are either dry milling or wet milling. Some materials need dry milling and some need wet milling. On the basis of number of axes they are 3 axes, 4 axes or 5 axes. As mentioned before, 5-axis milling machines are used in almost all cases as processing machines for CAM systems. Restorations milled with a 5 axes milling unit can mill undercuts in all directions and thus have a greater accuracy than 4 and 3 axes units [29]. A rotary cutting instrument with a smaller diameter results in a more accurate milling process. The accuracy of milling procedure is dictated by the diameter of the smallest bur. Any surface details less than the diameter of the milling bur will be over milled, and it will contribute to low retention of the restoration.

RPD frame-work with the fine interstitial detail or delicate clasp features cannot be guaranteed to be accurately produced by milling but by using 3D printed metal.

3D printing (Additive manufacturing)

Three-dimensional printing technology has received much attention in recent years. It has been hailed as a disruptive technology which will change manufacturing [30]. Edward Hems and Nigel Knott also have considered it as, "a bull which has entered the antique china shop and is running rampant among long-established manufacturing practices dependent upon expensive human skills and craftsmanship" [31]. However, the reality may be different and more studies are needed to prove whether 3D printed prostheses are as good as or better than the conventional prostheses.

It is the process of joining materials to make objects from 3D model data, layer upon layer. Once the CAD design is finalized, it is segmented into multi-slice images. For each millimeter of material, there are 5 - 20 layers in which the machine lays down successive layers of liquid or powder material that are fused to create the final shape [39].

It is that manufacturing approach which builds objects one layer at a time, adding multiple layers to form an object, hence described as additive manufacturing. Previously the technique was referred to as rapid prototyping because the methods were implemented to fabricate prototype models and patterns only. But recently, a shift to the manufacturing method has come up because of technical improvements of layer manufacturing processes. They are no longer exclusively used for prototyping and the possibility to process all kind of metals yields opportunities to manufacture real functional parts [39]. 3D printer is a simple robotic device or apparatus which works along with the CAD software. To create objects to print, CAD software is needed or data in the form of computed tomography (CT) data, CBCT data, and/or intraoral or laboratory optical surface scan data are needed. Many different printing technologies exist, each with their own advantages and disadvantages and the primary difference among them is related to developing the plane which represents the vertical component of the restorations. Some of the commonly used techniques are vat photo-polymerization method/stereo-lithography, photopolymer jetting (PPJ), selective laser sintering (SLS), binder jetting method, digital light processing (DLP) and fused deposition modelling (FDM).

In SLA method a stereo-lithography apparatus uses a scanning laser to build parts one layer at a time, in a vat of light-cured photopolymer resin [41]. This technology is commonly used for the industrial production of 3D printed implant drill guides [33]. Additional uses are in fabrication of facial prosthesis patterns, occlusal splints, burnout resin patterns, and investing flasks.

In PPJ technology, photo-jet-light sensitive polymer is jetted onto a build platform from an inkjet type print-head and cured [42]. A variety of materials may be used including resins and waxes for casting, as well as some silicone-like rubber materials [34].

In binder jetting method, powder is laid and a liquid binder is selectively jetted and solidified [43]. Powder binder printers (PBP) use a modified inkjet head to jet liquid droplets to infiltrate a layer of powder. A pigmented liquid, which is mostly water, is used to infiltrate into the powder, which is mostly plaster of Paris [30]. The resulting models are useful as study models or visual prototypes, but accuracy is limited and the models are fragile. This method has also been used to manufacture metallic parts from stainless steels, other iron alloys, copper and nickel super-alloys and for ceramic parts [43]. This can be a potential method for manufacturing complex geometries with fine features like that of cast partial denture [44].

The technology for manufacturing of objects from powder using a laser consists of two processes: selective laser sintering (SLS) and selective laser melting (SLM) [45]. In this technology, a scanning laser fuses a fine material powder, to build up structures. Laser beam hits the powder and creates a melt pool and the powder particles fuse together [33]. The term "Selective Laser Sintering" is used in the processing of polymers and ceramics, while in the manufacturing of metals and alloys the terms "Selective Laser Melting" (SLM) or "Direct Metal Laser Sintering" are used [45]. Polymers used in this process have high melting points (above autoclave sterilization temperature) and excellent material properties, making objects made in this way useful as anatomical study models, cutting and drilling guides, dental models, and for engineering/design prototypes [30]. The most versatile materials used include nylon, flexible elastomeric materials, and metal-containing nylon mixtures.

DLP method can be used to fabricate a single layer of the 3D object through spatially-controlled solidification of a photo-curable resin by using a projector light, either UV light or white-light [46].

FDM is one of the earliest 3D printing technologies. This technology works on the principle of extruding a thermoplastic filament material through a heated nozzle and the material hardens immediately after extrusion [47]. A commonly used material is the biodegradable polymer polylactic acid [32]. This or similar materials have been used as key components of scaffold structures for 'bio-printing'- a popular area for research in tissue engineering. This is the process that is used by most low cost 'home' 3D printers. It allows for the printing of crude anatomical models without too much complexity – for example, printing an edentulous mandible might be possible, but not a detailed maxilla [47]. More costly, more accurate FDM printers are available, and have application in anatomical study model making, but little use in dentistry or in surgery.

All the methods used for 3D printing share some features that distinguish them from subtractive manufacturing. Those features are: (i) incremental vertical object build-up (ii) no material wastage (iii) large objects produced (iv) passive production (i.e. no force application) (v) fine details production [39].

Considerable reduction in cost would be possible by using 3D printing technology as less material is wasted. 3D printing enables manufacture of functionally graded materials, which cannot be manufactured by milling [31]. Thus, it is expected that it will become one of the main manufacturing methods in the future.

Limitations and Future Expectations

There are some barriers to going digital in a Prosthodontic Clinic. Reluctance of dental practitioners to workflow disruption, absence of basic computer skills and unfamiliarity with digital technology, lack of access to new information, need of better office systems, need of training of staff and dentist to manage the equipment, initial costs and IT costs of managing large datasets, concern about security and privacy, technical and expert support, potential financial risks and poor evidence regarding the integrity of the digital solution are some of them [2,6,48-50]. The main barriers to dentists' adoption of new technology being awareness and emotion [6].

As mentioned before, with IOS and with optical impressions there is difficulty in detecting deep marginal lines. CBCT is useful for evaluating bone but, limitations currently exist in the use of this technology for soft tissue imaging [30,31]. Efforts are being directed toward the development of techniques and software algorithms to improve signal-to-noise ratio and increase contrast in evaluation of soft tissue. But, a factor that could influence the use of CBCT is the voxel size. By decreasing the voxel size the image spatial resolution increases but it also increases patient exposure to radiation by increasing the scan time [22].

Shape design by the CAD software is done in a static state without considering contact sliding movements of the upper and lower teeth, and technicians perform manual adjustments to the model after milling with the CAM [1,2,25]. It is difficult in practice to obtain motion data. Even in the more advanced system, a virtual articulator is implemented into CAD software to simulate a conventional semi-adjustable articulator [1]. It is therefore nearly impossible to design an optimal functional occlusal surface configuration for each individual patient.

Disadvantages of milling (subtractive manufacturing) are that some materials cannot be milled, a long time is needed for the processing, some shapes cannot be processed due to tool interference, and much of the material is wasted [28,29]. The main problem with Additive Manufacturing (3D printing) is that this type of manufacturing can cause differences in the final model production because of shrinkage during building, post-curing, and minimal thickness of the layer [30]. SLS technology have some health and safety requirements, and messy to work with [30,32].

It is expected that in near future more and more staffs and dentists will be trained to manage the digital workflow. Shape measurement by an intraoral scanner will be performed at ultrahigh speed, and a series of states in which the upper and lower teeth slide in contact will be regarded as a record of the positional relationship between the upper and lower jaws [1]. The occlusal contact state of each patient will be simulated by a CAD system without a virtual articulator. Such CAD software will be developed in the near future which will enable almost automatic design of an optimal occlusal surface form for each patient and manual alteration of the occlusal surface by a technician will not be needed [1].

Conclusions

Rapid advancements and improvements in digital technologies give an impression that the entire workflow in a Prosthodontic clinic will be changed to that of a completely digitalized clinic in very near future.

Conflict of Interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Bibliography

1. Ueda Y and Yamaguchi T. "History of and current situation regarding dental CAD/CAM systems and future perspectives". *Hokkaido Journal of Dental Science* 38 (2017): 104-110.

2. Joda T., *et al.* "The complete digital workflow in fixed prosthodontics: a systematic review". *BMC Oral Health* 17.1 (2017): 124.

3. Mangano F., *et al*. "Digital Dentistry: New Materials and Techniques". *International Journal of Dentistry* (2016).

4. Bhambhani R., *et al*. "Digitization and Its Futuristic Approach in Prosthodontics". *The Journal of Indian Prosthodontic Society* 13.3 (2013): 165-174.

5. Prithviraj DR., *et al.* "Revolutionizing Restorative Dentistry: An Overview". *The Journal of Indian Prosthodontic Society* 14.4 (2014): 333-343.

6. Cooper F L and Ludlow M E. "The Current Impact of Digital Technology in Prosthodontics. Digital White Paper". *ACP Digital Dentistry Resources* (2016): 1-11.

7. Shah N., *et al*. "Recent advances in imaging technologies in dentistry". *World Journal of Radiology* 6.10 (2014): 794-807.

8. S Ting-Shu and S Jian. "Intraoral Digital Impression Technique: A Review". *Journal of Prosthodontics* 24.4 (2015): 313-321.

9. Zimmermann M., *et al.* "Intraoral scanning systems - a current overview". *International Journal of Computerized Dentistry* 18.2 (2015): 101-129.

10. Mangano F., *et al*. "Intraoral scanners in dentistry: a review of the current literature". *BMC Oral Health* 17.1 (2017): 149.

11. Martin CB., *et al*. "Orthodontic scanners: what's available?". *Journal of Orthodontics* 42.2 (2015): 136-143.

12. Sakornwimon N and Leevailoj C. "Clinical marginal fit of zirconia crowns and patients' preferences for impression techniques using intraoral digital scanner versus polyvinyl siloxane material". *Journal of Prosthetic Dentistry* 118.3 (2017): 386-391.

13. Imburgia M., *et al*. "Accuracy of four intraoral scanners in oral implantology: a comparative in vitro study". *BMC Oral Health* 17.1 (2017): 92.

14. Aragón ML., *et al.* "Validity and reliability of intraoral scanners compared to conventional gypsum models measurements: a systematic review". *European Journal of Orthodontics* 38.4 (2016): 429-434.

15. Ahlholm P., *et al.* "Digital Versus Conventional Impressions in Fixed Prosthodontics: A Review". *Journal of Prosthodontics* 27.1 (2018): 35-41.

16. Goracci C., *et al*. "Accuracy, reliability, and efficiency of intraoral scanners for full-arch impressions: a systematic review of the clinical evidence". *European Journal of Orthodontics* 38.4 (2016): 422-428.

17. Schepke U., *et al*. "Digital versus analog complete arch impressions for single-unit premolar implant crowns: Operating time and patient preference". *Journal of Prosthetic Dentistry* 114.3 (2015): 403-406.

18. Muallah J., *et al.* "Accuracy of full-arch scans using intraoral and extraoral scanners: an in vitro study using a new method of evaluation". *International Journal of Computerized Dentistry* 20.2 (2017): 151-164.

19. John G P., *et al.* "Fundamentals of cone beam computed tomography for a prosthodontist". *The Journal of Indian Prosthodontic Society* 15.1 (2015): 8-13.

20. Venkatesh E and Elluru SV. "Cone beam computed tomography: basics and applications in dentistry". *Journal of Istanbul University Faculty of Dentistry* 51.3 (2017): S102-S121.

21. Shukla S., *et al.* "Role of cone beam computed tomography in diagnosis and treatment planning in dentistry: An update". *Journal of International Society of Preventive and Community Dentistry* 7.3 (2017): 125-136.

22. Pauwels R. "What Is CBCT and How Does It Work?" Maxillofacial Cone Beam Computed Tomography (2018).

23. De Cock J., *et al.* "Cone-beam computed tomography: a new low dose, high resolution imaging technique of the wrist, presentation of three cases with technique". *Skeletal Radiology* 41.1 (2012): 93-96.

24. Sahai S. "Recent advances in imaging technologies in implant dentistry". *Journal of the International Clinical Dental Research Organization Organ* 7.3 (2015): 19-26.

25. Ginat D T and Gupta R. "Advances in Computed Tomography Imaging Technology". *Annual Review of Biomedical Engineering* 16 (2014): 431-453.

26. Scarfe W C., *et al.* "Clinical Applications of Cone-Beam Computed Tomography in Dental Practice". *Journal of the Canadian Dental Association* 72.1 (2006): 75-80.

27. Jacobs R., *et al.* "Cone Beam Computed Tomography in Implant Dentistry". *BMC Oral Health* 18.1 (2018): 88.

28. Zarina R., *et al.* "Evolution of the Software and Hardware in CAD/CAM Systems used in Dentistry". *International Journal of Preventive and Clinical Dental Research* 4.4 (2017): 284-291.

29. Tariq F and Alghazzawi. "Advancements in CAD/CAM technology: Options for practical implementation". *Journal of Prosthodontic Research* 60.2 (2016): 72-84.

30. Dawood A., *et al.* "3D printing in dentistry". *British Dental Journal* 219.11 (2015): 521-529.

31. Hems E and Knott N. "3D printing in prosthodontics". *Faculty Dental Journal* 5.4 (2014): 152-157.

32. Quadri S., *et al.* "Rapid prototyping: An innovative technique in dentistry". *Journal of Oral Research and Review* 9.2 (2017): 96-102.

33. Gali S and Sirsi S. "3D Printing: The Future Technology in Prosthodontics". *Journal of Dental & Oro-facial Research* 11.1 (2015): 37-40.

34. Katreva I., *et al.* "3D-Printing in Contemporary Prosthodontic Treatment". *Scripta Scientifica Medicinae Dentalis* 2.1 (2016): 16-20.

35. Torabi K., *et al.* "Rapid Prototyping Technologies and their Applications in Prosthodontics, a Review of Literature". *Shiraz University of Medical Sciences* 16.1 (2015): 1-9.

36. Prasad S., *et al*. "3D printing in dentistry". *Journal of 3D Printing in Medicine* 2.3 (2018): 89-91.

37. Frey CB and Osborne MA. "The Future of Employment: How Susceptible are Jobs to Computerisation?". *Technological Forecasting and Social Change* 114 (2017): 254-280.

38. Ruthwal Y*., et al.* "Digital Impressions: A New Era in Prosthodontics". *IOSR Journal of Dental and Medical Sciences* 16.6 (2017): 82-84.

39. Abduo J., *et al.* "Trends in Computer-Aided Manufacturing in Prosthodontics: A Review of the Available Streams". *International Journal of Dentistry* (2014).

40. lliescu AA., *et al*. "Milling Machines Tools Used In CAD-CAM Technology Of Dental Prostheses". *Romanian Journal of Oral Rehabilitation* 10.4 (2018): 38-43.

41. Zaharia C., *et al.* "Digital Dentistry- 3D Printing Applications". *Journal of Interdisciplinary Medicine* 2.1 (2017): 50-53.

42. Mai Hang-Nga., *et al.* "Fit of interim crowns fabricated using photopolymer-jetting 3D printing". Journal of Prosthetic Dentistry 118 (2017): 208-215.

43. Parab ND., *et al.* "Real time observation of binder jetting printing process using high-speed X-ray imaging". *Scientific Reports* 9 (2019): 1-10.

44. Mostafaei A., *et al.* "Binder jet printing of partial denture metal framework from metal powder". *Materials Science and Technology* (2017).

45. Dzhendov D and Dikova T. "Application Of Selective Laser Melting In Manufacturing Of Fixed Dental Prostheses". *Journal of IMAB - Annual Proceeding* 22.4 (2016): 1414-1417.

46. Mu Q., *et al*. "Digital light processing 3D printing of conductive complex structures". Additive Manufacturing 18 (2017): 74-83.

47. Obregon F., *et al*. "Three-Dimensional Bioprinting for Regenerative Dentistry and Craniofacial Tissue Engineering". *JDR Clinical Research Supplement* 94.9 (2015): 143S-152S.

48. Ramilo R and Bin Embi RM. "Critical analysi of key determinants and barriers to digital innovation adotion among architectural organizations". *Frontiers of Architectural Research* 3.4 (2014): 431-451.

49. Van der Zande MM., *et al.* "Dental practitioners and a digital future: an initial exploration of barriers and incentives to adopting digital technologies". *British Dental Journal* 215.11 (2013): E21.

50. Ajami S and Bagheri-Tadi T. "Barriers for Adopting Electronic Health Records (EHRs) by Physicians". *Acta Informatica Medica* 21.2 (2013): 129-134.

Volume 18 Issue 7 July 2019