APPLICATIONS OF 3D PRINTING TECHNOLOGY IN DENTISTRY

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Abstract

In this study, applications of 3D printing techniques in dentistry sector are explained. In 3D applications, there are single tooth coating, bridge, implant tooth making, partial and prosthetic tooth making studies. These applications, which are made with 3d instead of manual according to the mouth of the patient, are longer lasting and useful. Therefore, 3d printing technology has started to be important and necessary in dentistry. It is preferred to use an abrasion resistant plastic material and porcelain material. The important point here is that a carcinogenic material should not be used as it is a study of oral and dental health. Such a study should be done by health and chemistry society.

Keywords: Teeth; Dentstry; 3D Prınter; Design

Introduction

The 3D printer, known as the technology of the future, is a machine that models an imaginary part in a computer environment and transforms it into tangible concrete objects in a short time. In usually, the 3D dental models (including 3D single tooth) used in CAD/CAM dentistry system are mostly obtained by optical digitizers, which is typically represented by using a watertight triangular mesh. The 3D dental model is an integral model without obvious blending boundary between the single-tooth and the soft tissues. Two adjoining teeth sometimes are fused together and without obvious tooth gap, due to teeth overlapping, lower measurement precision, and limited resolution triangulating methods during digitizing step. In order to satisfy the prerequisites of manufacturing the dental restorations and assessing the virtual dental behaviors, the teeth have to be independent of each other and keep the original shape of the real tooth.The accurate single-tooth shape restoration and extraction techniques for the 3D dental model play a vital role in CAD/CAM dentistry system. The use of 3D CAD models in dentistry has great advantages over conventional physical models. Many dental and maxillofacial surgery applications such as endodontic procedures [1], treatment of malocclusion problems [2] and treatment simulations require an accurate knowledge of the 3D shape of teeth. Physical models require physical space for storage, adding financial and logistic burdens,while virtual models are stored electronically [3].

Model retrieval is greatly facilitated, communication with other dental specialties is improved, and the traditional duplicating of plaster casts, handling, and shipping becomes obsolete.Several companies now offer virtual study models.

Proprietary software for virtual model analysis is provided by the companies, giving the clinician valuable tools for almost any application. The ability of 3D virtual models to represent the patient’s

dentition accurately and the validity and reproducibility of measurements on these models, have been extensively studied [4]. Because it is less time consuming, easier to use, and cost effective at comparable levels of clinical accuracy, a strong argument can be made for the routine application of computer-based 3D models [5].

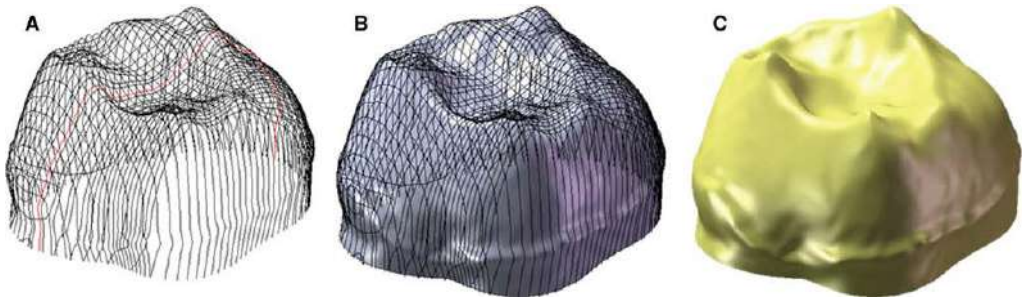

Fig.1. CAD models levels [1]

a - Mesh model b - surface model c - 3D Solid model

3D Print

The 3D printer is a machine that manufactures physical models by adding layers of material to the 3D data without sending any mold, model or similar tool designed by computer aided design (CAD) programs. Three-dimensional printing is the process of printing any three-dimensional object designed in the virtual environment in solid form. Devices that perform this process are called 3Ds. The prints can be made with the use of raw materials in many species. Raw materials which are the most common usage on the basis of regular users are hard plastics called PLA and ABS. There are 3Dthat can print on different types and techniques. The working principle of 3Dwith the most common use is based on virtually dividing any three-dimensional object created in the computer into layers and printing each layer in a superimposed manner by pouring the melted raw material.

3D printing technology began in the 1980s. However, after 2010, the name has become more pronounced and has become more widely used today. The reason for this is that more and more entrepreneurial firms invest in this technology, the interest of academia, the advantages and advantages of technology in many areas, and the reduction of production costs. The first 3D was produced in 1984 by Chuck Hull of 3D Systems. The fields where 3D printer is used and applied are shown in Fig.2 Accordingly, it is understood that the medical and dental area 3D printers are used in a significant amount in these areas. Printing prosthetic parts, organs, medical models, synthetic skin, etc.

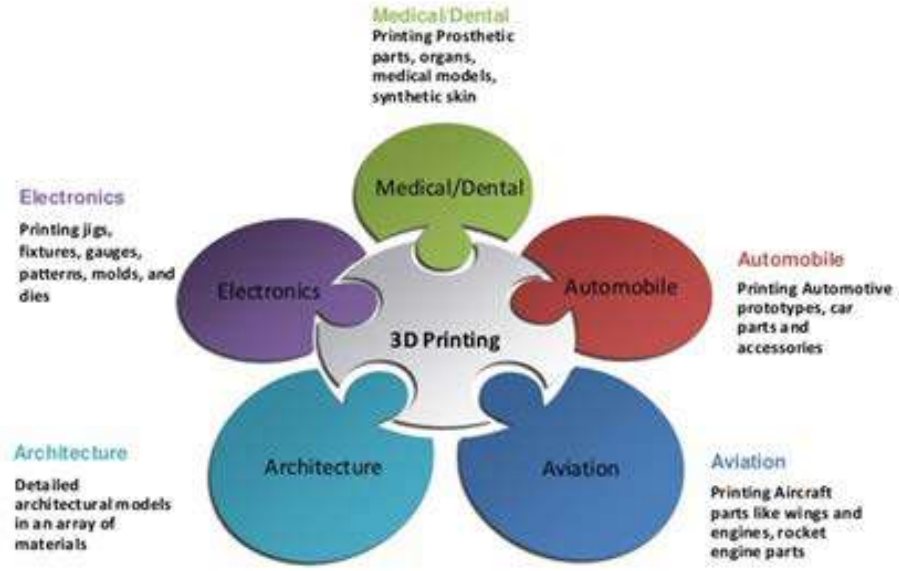

Fig.2. 3D Printing using fields [7]

Today, many companies have begun to produce and sell 3Ds. As of 2012, the market volume of three-dimensional letters has reached $ 4.1 billion, an increase of 43% compared to 2015. 3Dcan print their own parts in large quantities. Almost all mechanical parts except electronic components and motors can be printed by 3D printer. It is predicted that the features of the 3D itself will be able to print completely in the future.

Three dimensional designs can be designed with CAD (Computer Aided Design) programs in computer environment. In addition, any object can be scanned with three-dimensional scanners and passed as a virtual three-dimensional design. Three-dimensional scanning is done by analyzing an actual soil and collecting data. It is now possible to print an individual copy of any objet that is scanned in three dimensions. Designing in 3d is a difficult and demanding process for many computer users. As shown in Fig.3, 3d printing is presented with a simple look. The orange flament material is taken from a roller and melted with the heater nozzle to form letters or numbers.

Fig.3. Simple the 3D Printing [7]

Conventional methods and applications in dentistry, structured-light scanners, laser scanners or intraoral scanners have t he potential to offer excellent accuracy with a more comfortable experience for the patient and more efficient work flow f or the dentists' office. In the paper a new CAD approach to reconstruct the complete molar shape (enamel, dentin and pulp) given only data of the external surface of the crown is described. It offers the benefits of in housing model creation f or the dentist. The method allows to start from t he data f rom a non contact system and obtain an accurate complete CAD model of a molar which can be then used in several dentistry applications such as for dental CNC milling machines or to test new materials by using virtual simulations (for example analysis on restored teeth).

3D Print Methods

The printing process starts in the computer environment and is completed by the printing of the printer. Some 3Dcan print by reading the design file on the memory card without the need for a computer connection. 3D design files are sliced through computer software and converted into three-dimensional printable file format. These files are in STL file format. This file contains information about all the movements of the 3D during printing and when it will start to cast raw materials. The resolution of the printer depends on the thickness of the layer and the motion sensitivity on the x-y axes. Typically the print thickness is 100 µm (250 DPI). But some printers can print at a much higher resolution. 16 µm (1,600 DPI). Printing time varies according to printer and printing design. Fig. 4. Shows a key mascot 3d printing steps.

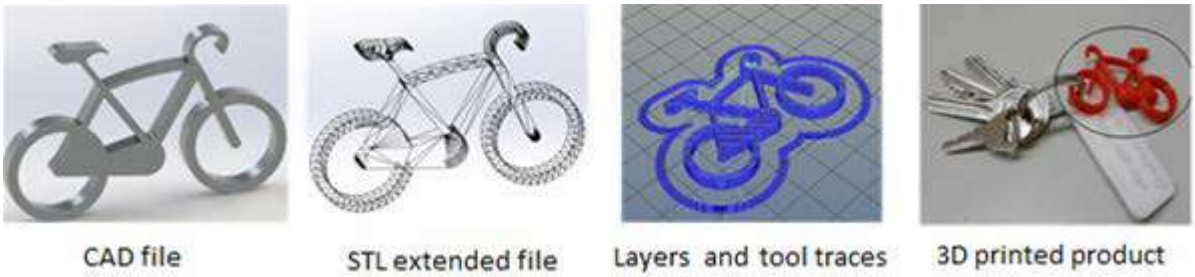

Fig.4. A key mascot 3d printing steps [6]

SLA (Stereolithografi) technology

The layer of the model is drawn on the surface of a liquid polymer that provides laser or beam solidification, and after each layer is formed, the model is lowered by a layer thickness by Z axis. Lowering works with similar mechatronic systems such as hydraulic, pneumatic, screw-nut system.

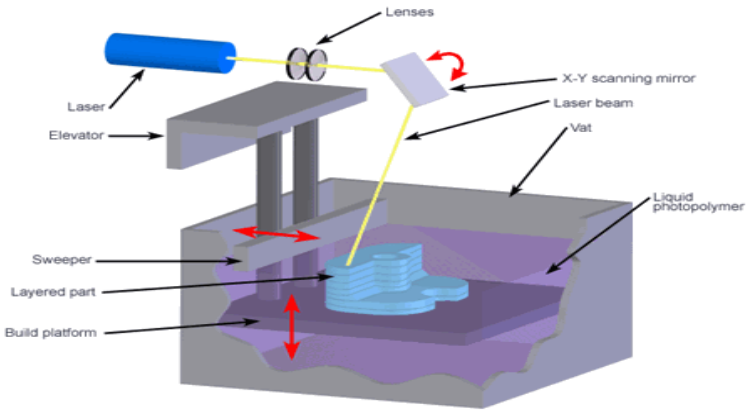

Fig.5. SLA 3D Printing [8]

FDM (Layer Accumulation Modeling) technology

The most widely known and used in the world is FDM technology (Fused Deposition Modeling) or stacking layer technology by combination. This technique uses thermoformable thermoplastic (PLA, ABS) materials. Materials Using in FDM Technology; ABS, PLA, PET, Nylon 3B Filament, Metal-looking 3D Filament,Ceramic 3D, Filament, Wooden 3D Filamen, 3D Shining Filament in the Dark, Carbon Fiber PLA, Polycarbon ABS, UV Sensitive ABS. FDM 3D Printing shown in Fig. 6.

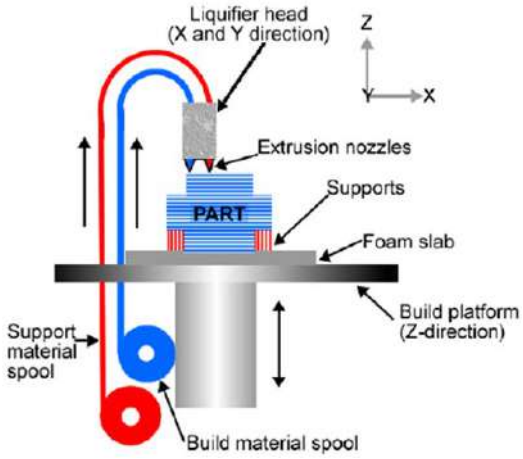

Fig.6. FDM 3D Printer [8]

SLS (Seçici Lazer Sinterleme) technology

Here, metal dust is laid on the volumetric table, the laser beams are projected onto the powder material, and the layers are brought to the field by melting from the dusts in the area of the model geometry, and after each layer is formed, the model is lowered down to a layer thickness by Z axis. The metal powder is reapplied and the process is continued to form the model. Depending on the power of the laser technology, many different materials can be used, such as metal, plastic and ceramic. Also polyamide, glass-added polyamide, this material is used in metal materials. SLS 3D Printer shown in Fig. 7.

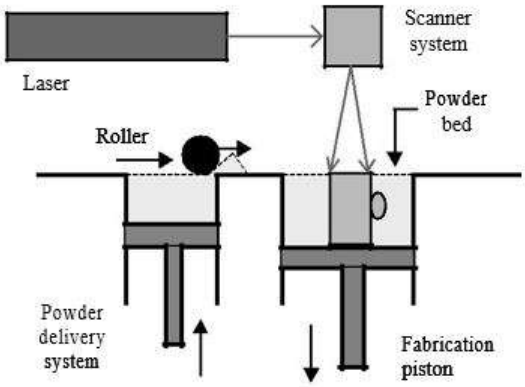

Fig.7. SLS 3D Printer [8]

Polyjet technology

The pattern is formed by spraying the layer of the photopolymer resin onto the plate and curing with UV light. Polyjet technology is a state of the art layered production method that uses multiple materials together. Using materials in PolyJet Technology; Digital ABS, Fullcure-720, Vero clear, Tango, Endur. SLA 3D Printer shown in Fig. 8.

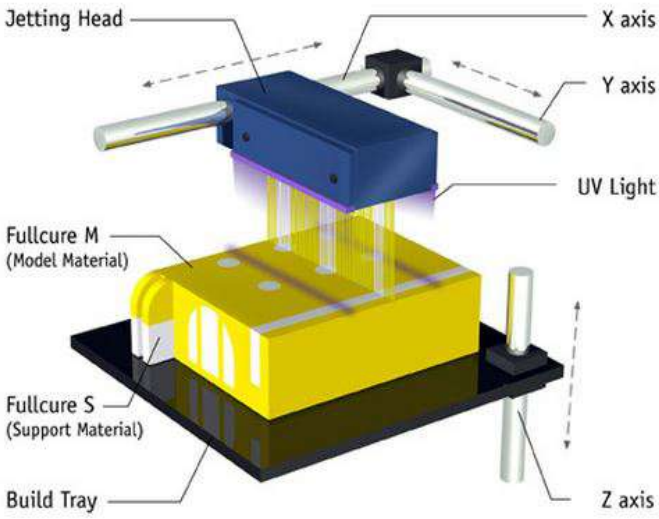

Fig.8. SLA 3D Printer [8]

DMLS (Direct Metal Laser Sintering) technology

Devices using this method create layers by spraying molten metal through a small hole. Costs are high but sensitive metal parts can be produced. DMLS 3D Printer shown in Fig. 9.

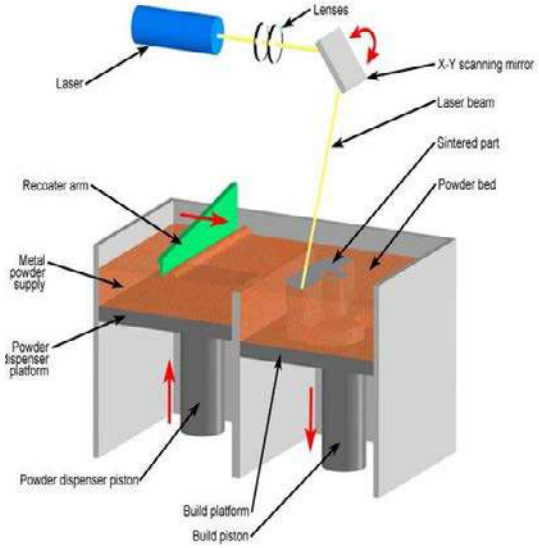

Fig.9. DMLS 3D Printing [8]

3D Printer programming

Ardunio is a microcontroller platform with open source code and hardware. Arduino is the biggest feature on the breadboard. Breadboard is an experimental boar that allows you to set up and monitor the prototype of the ship without soldering. Here, the tooth properties taken by the scan from the patient's mouth go directly to the ardunio circuit board, and then the tooth model is sent to the extruder motor by modeling this tooth characteristic. Fig. 10 shows using ardunio circuit board in 3d print dentistry.

Fig.10. Ardunio circuit board in 3d print dentistry [9]

The motors that provide x, y, z (two action) movements work with commands from the succession card, as shown in Figure 11 on the 3D printer. In the same way, the nozzles and extruders, which provide the accumulation of the material and form the heating, also work with the commands from the ardunio. Nozzles First form a layer like a floor painting on a heated build plate.Extruder thermistors prevent overheating so that the material does not burn.

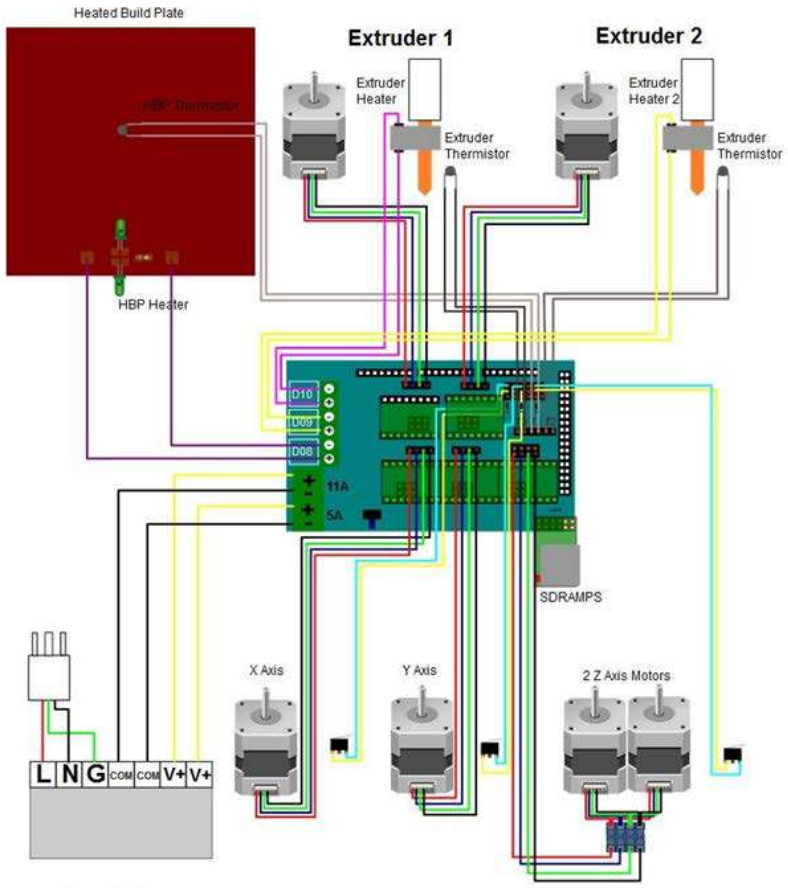

Fig.11. Parts and ardunio circuit board in 3d print [9]

3D Printer Applications Used in Dentistry

The dental benefits of 3D printer application are; High accuracy positioning of implants, Obtaining the prosthesis or cron coating parts,which can not be obtained with CNC (Computer Nümerical Controlling) or conventional methods with a more precise 3D printer, High process speeds, Zero waste and low cost, Since the workflow process is digitalized, the least error, Possibility to work with biocompatible materials of dental materials (Resins). Intra oral digital scanner is used to scan the tooth structure or appearance of the patient's mouth. The model of the desired tooth structure according to the scanned image is modeled by drawing in the CAD (Computed Aided Design) program. The modeled tooth is sent to the 3D printer. The crown coating (metal or acrylyc) made from a 3D printer is attached to the mouth of the patient as shown in Fig. 12. DMLS method is preferred as a 3 D printer process in Crown coatings.

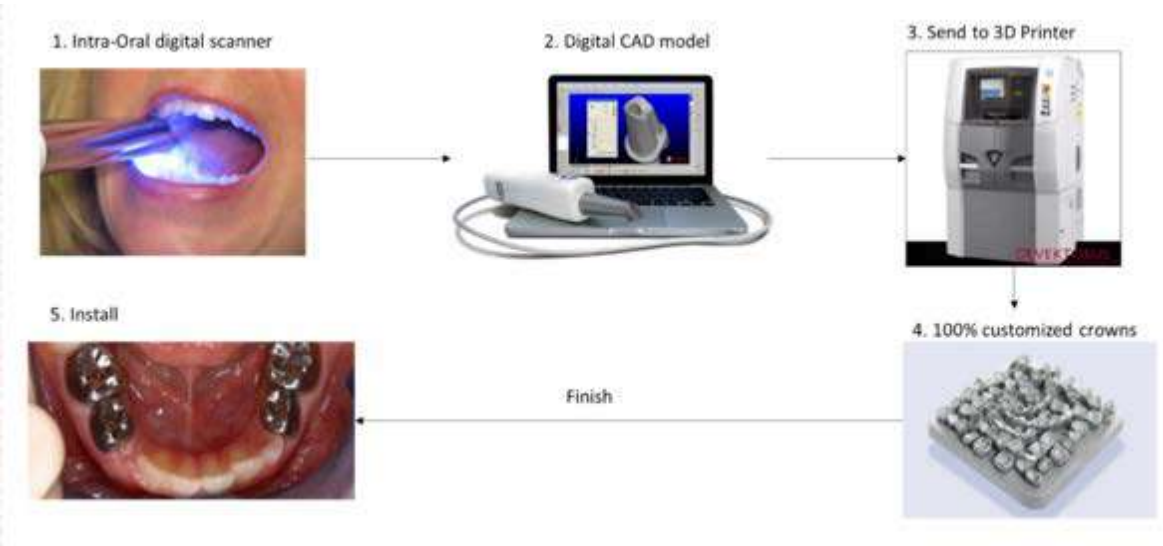

Fig.12. A product levels of crown teeth in patient mouth [9]

Bridge

3D printer technology is important in plant construction. Today it is used effectively. As seen in the above, bridge production is done. The term bridge dent means the group used in dentistry. These teeth are the production options that are produced before the prosthesis.1-2-3-4 as in members. the total prothesis production option is approached as the number of members increases in these groups. In the classical system, pre and robust teeth are used as bridge supporting legs. But now bridge legs are made as implant instead of solid teeth. Bridge group teeth are also produced in 3d printer. Fig 12 shows fixed partial denture (bridge). In other words, a 3-member bridge with an implanted foot is seen in Figure 12.

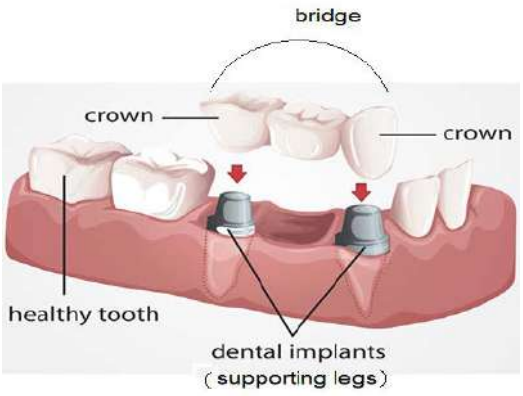

Fig. 12. Three members of crown and implant [9]

The 4 and 5 member 3D printed bridges are shown in Figure 13.

Bridge (5 members) Bridge (4 members)

Fig .13. Bridge of five and four members [9]

The SLA method is preferred as a 3 D printer operation in bridge coatings.

Crown

Crowns are protective coatings that are glued to teeth to protect teeth that have not been drawn, decayed, and for a longer period of time. They are fixed by sticking on the main tooth. The skins of the covering are glued in such a way that they do not get air and water and are leakproofed. The patient's skin to be covered is first subjected to retension and smoothing. Then it is glued with the adhesive called cement. These are illustrated in Figures 14 and 15. DMLS method is preferred as a 3 D printer process in Crown coatings.

Fig.14. Crowns [9]

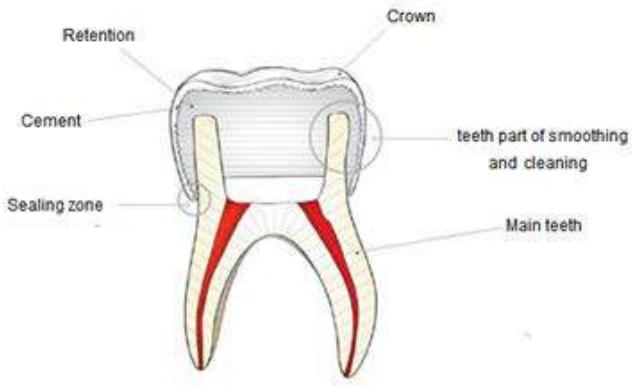

Fig.15. Cementing of crown [10]

Total and Parcial Prothes

In total and parcial prosthesis, SLA method is generally used as 3D printer method. Figure 16 shows the state of the total prosthesis on the 3D printer.

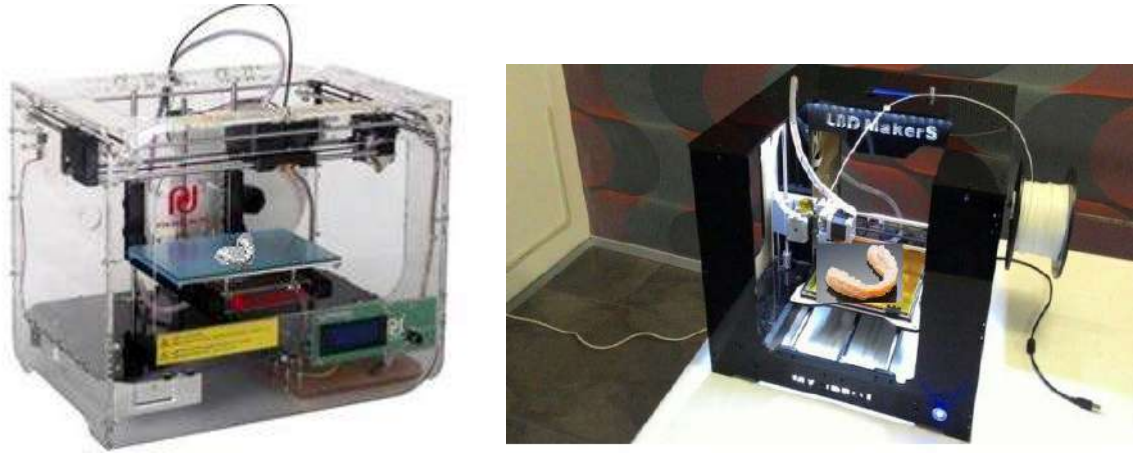

Fig.16. Total prothes and 3D Printer [10]

If the parcial prosthesis is metal, the DMLS method is used. The waxy state (proof color) and the finished state (metal state) of a parcial prosthesis are shown in Fig.17

Fig.17. 3d printed state of a parcial prothes model [7]

Total proteses are seen in Figure 18. Protective and transparent prostheses are esthetically preferred prostheses. In addition, the denture-based dentures are not aesthetic but are made in 3D printers to protect the teeth and mouth structure of the athlete in box matches.

Fig.18. 3d printed state of a total prothes model [7]

İmplant

The concept of implantation, which means implanting a non-female tooth at birth into the mouth of the patient, has recently become important in terms of oral health. In discussing the effect of metal screws used at implantation on the jawbone, it is more prevalent than bridging and crowning methods. If they endure an economic outcome, sometimes they use the choice of implanting all oral teeth totally. Figure 19 shows the implant crown coating. The implant screw is also shown. The disadvantage of Crown coating is shudder; besides the dental decay to be covered, the intact parts

must also be shaved. Because the crown does not sit completely in the tooth. This leveling made in consideration of the adhesion, damages the toothy areas especially the enamel layer. If carcinogenic and economical disadvantages are not taken into account, the implant method is preferred over crowns.

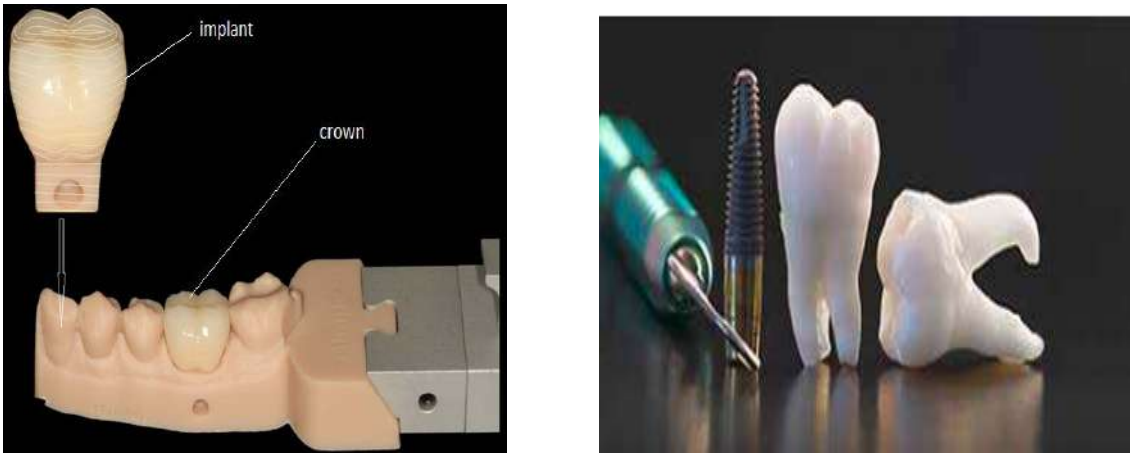

Fig.19. Single members of crown and implant with screw [8]

Figure 20 shows the relationship between the implant and the jawbone. The implant, called dental implantation or grafting to the jawbone, is secured to the female bone by means of a screw. There is a special task here for jawbone cells. Because of the impact of the operation and to break the fractures are required.

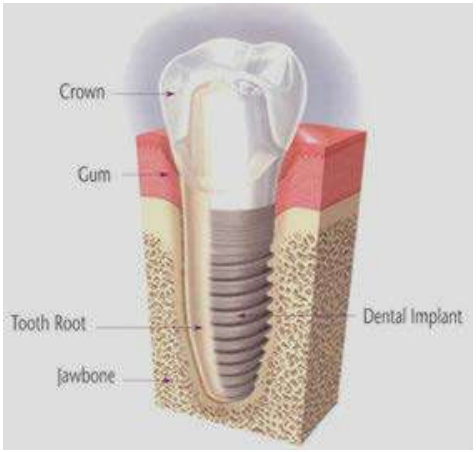

Fig.20. The jawbone and implant with screw [8]

Single and Array product in 3D printers

In dentistry, dental production is done as a single, as in multi or array dental production. The bridge includes the meaning of a jacket worn over the model. In the 3 D printer, Acrylic material is solved from the filament and layered on the model sprue. This occurs due to the melting of the nozzle in acrylic material. Figure 21 shows the production of a small molar crown coating with a 3 D printer alone.

Single product in 3D printers

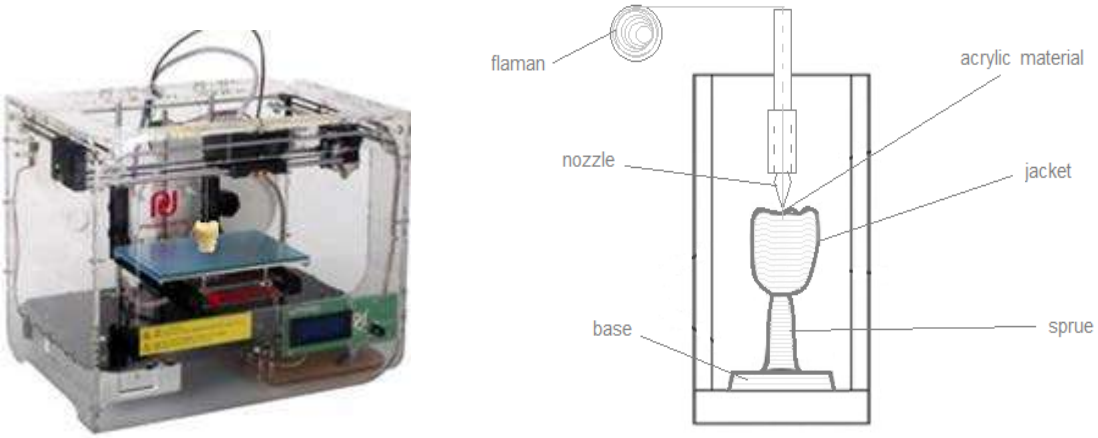

Fig. 21. Application 3D printer for small molar teeth [9]

Figure 22 shows the teeth made in 3D printer as single small and big molar. These teeth are the teeth to be used for implant application or crown coating application.

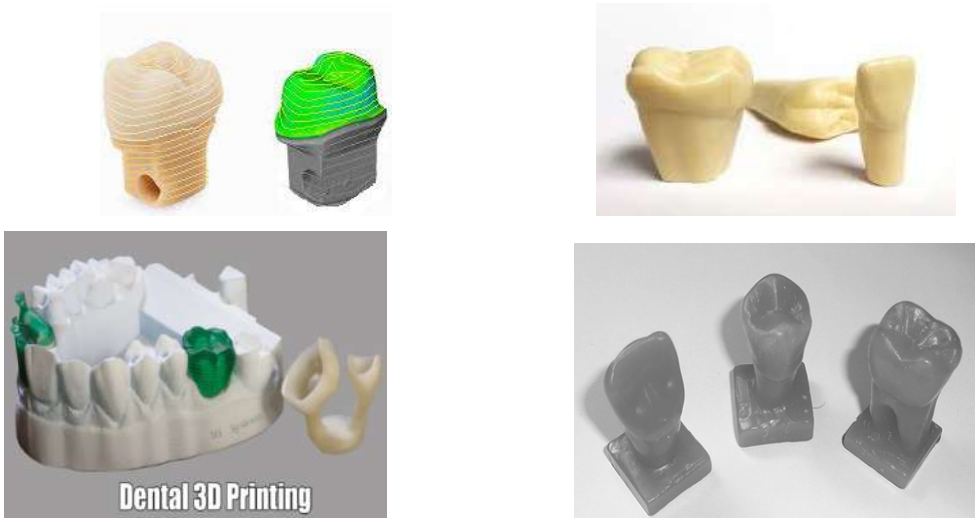

Fig.22. Applicated of small and big molar teeths [9]

Array product in 3D printers

Array of temporary crowns printed in E-dent material on envisiontech 3D Printing system. Multiple crowns and full dental production can be done in 3 D printers as arrays. There is a need for a pre-architectural design and layout model for this production. Because, the more optimal design is made, the more the optimum number and quantity of arrays arise. In other words, production capacity and capability increase. Figure 23 shows the application of the molar teeth for implant and 3D print.

Fig.23. Applicated of Design of molar teeth for implant and 3D print [10]

Applicated of arch models built in plaster like material on 3D Printing system shown in Figure 24.

Fig. 24. Applicated of Arch models built in plaster like material on 3D Printing system [10]

Conclusion and 3D Printer Technology in Future

Children will have the chance to make their own game with a three-dimensional toy data downloaded from the internet.If any part of the home appliance is broken, it is enough to pay only for the necessary geometry and material information, rather than bringing it directly from the factory.In the field of medicine, the production of special titanium bone fragments, materials and dentures suitable for orthodontic uses will become widespread. At Oxford University, scientists have succeeded in producing human stem cells with 3D printers, which will be used to create organs in the future. This means that in the near future, the organs that people need can be produced in a 3D compatible with the human body. With to 3D printing technology, purchased products will have all the features that are required. For example, shoes suitable for the foot structure of a person or clothes suitable for their expectations can be produced easily. From new car designs to a wide range of interior design to home furnishings will accelerate, so the acceleration of innovation will also increase.

A possible mistake made with 3D Printers is that the product will be noticed and can be fixed at the design stage. For example, if a part of a machine imported from abroad is required, it may be difficult to obtain this part by conventional methods, in terms of cost and time. With 3D data sharing of only the required part of the computer, this part can be produced in individual systems or in Digital Services. 3D printers will also increase the number of parts used for aerospace and the weight of parts, thereby boosting efficiency. European giant aircraft maker Airbus has begun to produce more than 1000 pieces of aircraft in industrial 3D printers. This also signaled in the future that an entire aircraft could be produced with industrial 3D printers. The jet engine, produced by the world's first three-dimensional printing technology, has been exhibited at the Australian International Air Show 2015 [6].

Acknowledgments

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