International Journal of Science and Healthcare Research
Vol.4; Issue: 4; Oct.-Dec. 2019
Website: www.ijshr.com
Review Article *ISSN: 2455-7587*

Rapid Prototyping in Dentistry

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ABSTRACT

The technique of rapid prototyping allows quick and automatic reconstruction of 3 dimensional (3D) model of a part or a product using 3D printers or stereolithography techniques. It has various applications in dentistry such as maxillofacial prosthesis, zirconia prosthesis, implant surgical guides, frameworks of removable and fixed prosthesis, wax patterns for dental prosthesis. It demands high artistic skill levels and allows achievement of high aesthetic skills. This review aims to discuss rapid prototyping and the various methods along with applications in dentistry.

Keywords: rapid prototyping, dentistry, 3 dimensional (3D) model

INTRODUCTION

Rapid prototyping is a technique which allows fabrication of a physical part or assembly using three-dimensional computer aided design (CAD) data and construction of the Rapid prototyping (RP) technologies mostly used manufacturing methods which depended on the manufacturing basics to create a custom made style and precise physical form in a short time. [1-3] ″It is a promising powerful technology that has the potential to revolutionize certain spheres in the ever changing and challenging field of medical and dental science″. The procedure aims to build prototypes (working models) within a short time to product and test different design features, thought, theories, functionality as well as results and performance in special cases. [4]

The first method for rapid prototyping was introduced in the 1980s in the field of engineering for the fabrication of a solid model based on a computed file. [5] In the past two decades, an improvement in medicinal science has been noticed clearly, different engineering applications can be the cause of this improvement. Dentistry is the branch of medicine which has the longest imitation of fusing engineering solutions and RP is becoming more attractive in dental applications. Concerning dental prosthetics various technologies and methods has been presented which permit production of exactness, specially designed, ideal dental substitution. Concerning dental technology, research has shown that laboratory crafting techniques can be replaced with a combination of CAD and CAM. [6,7]

The most common type of technologies that are adopted in dental practice are stereolithography (SLA), inkjet-based system (3DP), selective laser sintering (SLS), and fused deposition modeling (FDM). While various materials can be employed in these technologies; wax, plastics, ceramics, and metals are commonly used by several studies in dentistry. [8,9] The chosen material which is in powder, liquid, or solid state added inside the machine in a progression of thin layers, it can be used depending on the quality of the intended form and the type of machine.

1. Stereolithography: This technology used since the mid 1980s. Stereolithography (SLA) Production Printers build accurate parts directly from 3D CAD data. The part is created layer by layer, with each resin layer built on top of the next until the part is complete. Additive manufacturing or 3D printing technology is employed to fabricate prototypes, models, patterns, as well as production parts. [10,11] When an SLA part is complete, it is cleaned in a solvent solution to remove wet resin remaining on the part surface. Afterward, the part is put in a UV oven to cure it, completing the resin printing process. European Commission considered SLA as the best method for educational purposes and it preferable for exercising on surgical planning before surgery. [12] SLA-made surgical drill guides have been proved to benefit from high precision by several well-documented researches. It is used also to produce the impression for reconstructive surgeries and sub-periosteal dental implant surgery.

2. Inkjet-based system (3D printing - 3DP): It is an additive rapid prototyping technique. The machine builds frameworks in a manner similar to that of ink jet printing. [13] 3DP is a layer by- layer technique which continued progressively till the prototype is totally manufactured. This machine uses a single jet each for a plastic build material and a wax-like support material, which are held in a melted liquid state in reservoirs. The liquids are fed to individual jetting heads which squirt tiny droplets of the materials as they are moved in X-Y fashion in the required pattern to form a layer of the object. The materials harden by rapidly dropping in temperature as they are deposited. After an entire layer of the object is formed by jetting, a milling head is passed over the layer to make it a uniform thickness. The process is repeated to form the entire object. After the object is completed, the wax support material is either melted or dissolved away. The machine builds wax patterns of full crowns and frameworks in a manner similar to that of manual waxed restorations.

Due to its high tolerance, 3DP technology is not useful for impression purposes as SLA, this tolerance considers as a problem during creating delicate dental models such as casting patterns while during creating educational models it does not matter, however, it can be helpful for exercising the surgical. [14] The most outstanding feature is the ability to produce extremely fine resolution and surface finishes, essentially equivalent to CNC machines. The technique is very slow for large objects.

3. Selective laser sintering (SLS): Firstly discovered and developed in the middle of 1980s by Dr. Carl Deckard and Dr. Joe Beaman, it is an additive manufacturing technique which employed is a process of fusing together layers of specified powder material into a 3D model by a computer-directed laser. [15] It creates the desired three dimensional shape solid mass by fusing small particles powdered materials like plastic, metal, ceramic or glass powders with a high power laser (CO2 laser) so that heat from the laser need only elevate the temperature slightly to cause sintering. This greatly speeds up the process. The process is repeated until the entire object is fabricated. After the object is fully formed, the piston is raised to elevate it. Excess powder is simply brushed away and final manual finishing may be carried out. SLS technique has significant advantages in dentistry, particularly prosthodontics, since various thermoplastic materials such as nylon composite, investment casting wax, metallic materials, ceramics and thermoplastic composites can be used in this method. [16]

4. Fused deposition modeling (FDM): FDM is the second most widely used rapid prototyping technology, after stereolithography. In this system, supplied materials are released from a coil with a plastic filament in to an extrusion nozzle head. This system operates in three axes, essentially, drawing the model one layer at the same time. As the machine nozzle is moved over the stand table in the required trajectory, it drops a thin bead of extruded

plastic the firs. It is then heated to a free-flowing semi-liquid form. [17] The motion of the nozzle head is controlled by a processor and traces and deposits the material in extremely thin layers onto a subsidiary platform. The nozzle is heated to melt the plastic and has a mechanism which allows the flow of the melted plastic to be turned on and off. As the nozzle is moved over the table in the required geometry, it deposits a thin bead of extruded plastic/wax to form each layer. The plastic/wax hardens immediately after being squirted from the nozzle and bonds to the layer below. The entire system is contained within a chamber which is held at a temperature just below the melting point of the material. This technology permit designing of a wide range of materials and colors like wax of investment casting and medical grade ABS. FDM is suitable for the fabrication of bone model.

CONCLUSION

RP technologies play a very important role in dental application and it is noticeable that using of its models in dentistry will be widened in the future with continuous evolution of it. It will be useful in many fields of dentistry such as planning for surgery and designing for prosthodontics. In medical applications, the object or part to be modelled often, but not always, exists physically (anatomical structures of the patient's body) and building medical models essentially starts with acquiring data such as CT cross-sectional images, preprocessing of collected data to provide a format that a CAD package or a RP system can recognize and finally linking with RP technologies to obtain the desired physical models. Although several attempts have been made to further customize the technique described above for using in dentistry but it seems that in near future many other methods will developed which could change the traditional dental practices. Dental replacements can be manufactured in a layer by layer manner directly from a model created by the computer easily and quickly with different RP technologies without neither using special tools for each particular part nor involvement of the user. The drawbacks or limitations of the RP technology include complicated machinery and dependency on expertise to run the machinery during production, the high cost of the tools. With time, more sophisticated implementations of RP will be available to be more benefit for more patients.

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How to cite this article: Negi P, Jaikaria A, Kukreja S. Rapid prototyping in dentistry. International Journal of Science & Healthcare Research. 2019; 4(4): 113-116.

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