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RESEARCH ARTICLE

CONCEPT OF RAPID PROTOTYPING AND ITS USES IN DENTISTRY.

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Abstract

In prosthodontics, introduction of CAD/CAM technology is a milestone for restorative and fixed prosthesis. This has reduced both chair side and laboratory time and has better patient acceptance. Rapid prototyping is one of the technologies in CAD/CAM which is mainly introduced for industrial purpose. This rapid prototyping technology develops 3D physical models using additive or subtractive process. There are many techniques in rapid prototyping. In prosthodontics it has several applications. This technology may change the traditional prosthodontics. In this paper we are going to discuss about rapid prototyping, different techniques and their application in prosthodontics.

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Introduction:-

The word prototyping was first used in engineering to describe the act of producing a prototype, a unique product, the first product, or a reference model. In the past, prototypes were handmade by sculpting or casting, and their fabrication demanded a long time. Any and every prototype should undergo evaluation, correction of defects and approval before the beginning of its mass or large scale production. Prototypes may also be used for specific or restricted purposes, in which case they are usually called a pre-series model. Rapid prototyping (RP) techniques, also termed solid free form fabrication (SFF) or layered manufacturing, have been employed to build complex 3D models in medicine since the 1990s. In 1987, Brix and Lambrecht used, for the first time, a prototype in health care. It was a three-dimensional model manufactured using a computer numerical control (CNC) device, a type of machine that was the predecessor of rapid prototyping. However, it was only in the 1990's that an actual three-dimensional model was built to reproduce the anatomy of a patient based on CT images obtained during that patient's examination.¹ Based on this concept, all rapid prototype technologies create their three-dimensional models by means of addition of layers of a material that will fuse to give shape to the object previously planned.

Basic Principle of Rapid Prototyping processes:-

RP process belongs to the generative (or additive) production processes unlike subtractive or forming processes such as lathing, milling, grinding or coining etc. In which form is shaped by material removal or plastic deformation. In all commercial RP processes, the part is fabricated by deposition of layers contoured in a (x-y) plane two

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dimensionally. The third dimension (z) results from single layers being stacked up on top of each other, but not as a continuous z-coordinate. Therefore, the prototypes are very exact on the x-y plane but have stair-stepping effect in z-direction. If model is deposited with very fine layers, i.e., smaller z-stepping, model looks like original.

RP can be classified into two fundamental process steps namely generation of mathematical layer information and generation of physical layer model.²

Stereolithography (SL):-

Stereolithography (SL) is the oldest rapid prototyping technology and known all over the world. Materials used are photopolymers such as acrylates, epoxies, filled resin, and colored resin.¹ In this process photosensitive liquid resin which forms a solid polymer when exposed to ultraviolet light is used as a fundamental concept. Due to the absorption and scattering of beam, the reaction only takes place near the surface and voxels. A SL machine consists of a build platform (substrate), which is mounted in a vat of resin and a UV Helium-Cadmium or Argon ion laser. The laser scans the first layer, platform is then lowered equal to one slice thickness and left for short time (dip-delay) so that liquid polymer settles to a flat and even surface and inhibit bubble formation. The new slice is then scanned.² The thickness of the layers that generate prototypes using SL is 0.025 mm, which results in a surface of good quality.¹

Fused Deposition Modeling (FDM):-

Materials used are thermo plastics such as acrylonitrile butadiene styrene (ABS), polycarbonate, elastomers and waxes. In Fused Deposition Modeling (FDM) process a movable (x-y movement) nozzle on to a substrate deposits thread of molten polymeric material. The build material is heated slightly above (approximately 0.5⁰ C) its melting temperature so that it solidifies within a very short time (approximately 0.1 s) after extrusion and cold-welds to the previous layer.² The thickness of the layers that generate FDM prototypes is 0.178 mm, which generates a rough surface of poor quality.¹

3D Printing:-

The machine has a reservoir for one type of powder, which may contain mixtures of material, such as plaster and starch, a platform that moves horizontally and down while the powder solidifies, a roller to distribute and evenly spread the powder to the fused, and a print head that is filled with the binder. Materials which can be used are polymers, ceramic, metal powder with binder. The thickness of the layers generated by powder binding is 0.1 mm, which gives the prototype a slightly irregular surface, low resistance and low accuracy due to the nature of the material used in its fabrication.¹

Inkjet – Polyjet:-

The production begins with the deposition of successive layers of acrylic resin that are stacked up to create the prototypes. During production, two types of material are used: acrylic resin, which of the object, and a gelatinous material to fill empty spaces during produce support structure for the prototype. The gelatinous material is easily removed later using a jet of water. The thickness of build layers in this technology is 0.016 mm, which ensures excellent surfaces finish and the reproduction of small details.¹

Selective Laser Sintering:-

Materials which can be used are polymers, ceramic, metal powder with binder, sand with binder, plastics, nylon and elastomers. This technology uses a laser beam that fuses powder particles of the material to be used. After a layer is laser-sintered, a new powder layer is added to continue the production of the prototype. The thickness of the layers in this technology is 0.1 mm, and the objects have a slightly irregular, highly porous surface.¹

Laminated object manufacturing:-

In this process, materials that are relatively cheaper like paper, plastic roll etc. can be used. Parts of fiber-reinforced glass ceramics can be produced. Large models can be produced and the building speed is 5-10 times as compared to other RP processes. The limitation of the process included fabrication of hollow models with undercuts. Large amount of scrap is formed. There remains danger of fire hazards and drops of the molten materials formed during the cutting also need to be removed (Pham and Demov, 2001). After completion of the part they are sealed with a urethane lacquer, silicone fluid or epoxy resin to prevent later distortion of the paper prototype through water absorption.²

Applications of rapid prototyping in dentistry:-

As in many branches of medicine, rapid prototyping has been also used in dentistry for a range of dental specialties including oral and maxillofacial prosthodontics, surgery, orthodontics and in operative dentistry.³ Prosthodontics applications are explained below. In surgery rapid prototyping technology is used to build anatomic medical models, this represent a new approach for surgical planning and simulation. These techniques allow one to reproduce anatomical objects such as 3D physical models of the skull or other structures, which give the surgeon a realistic impression of complex structures before surgical intervention. The shift from the visual to the visual-tactile representation of anatomical objects introduces a new kind of interaction called “touch to comprehend.” Prototypes can and should be used in several situations, such as:

- ❖ Evaluation of asymmetrical features
- ❖ Reconstruction of symmetrical structures using mirroring
- ❖ Fracture assessment
- ❖ Modeling rigid internal fixation plates and screw selection
- ❖ Modeling osteogenic distractors
- ❖ Calculation and adaptation of bone grafts
- ❖ Tumor assessment
- ❖ Fabrication of surgical guides.¹

In restorative dentistry the utilization of lab-based CAD/CAM technology for metal-free ceramic restorations .In this way time consuming and/or difficult parts in restoration making can be easily implemented even without human intervention. In orthodontics using state-of-the-art CAD/CAM technology, the two normally separate processes of bracket production and bracket positioning are fused into one unit. Another innovative use of the CAD/CAM technology was to create an overcrown able to open the bite through clinical crown lengthening of the mandibular second premolars.³

The application of RP techniques for prosthodontics:

Fixed partial denture:-

1. Wax pattern fabrication
2. Metal prosthesis fabrication
3. zirconia prosthesis fabrication

Implants-The production of surgical guides fabrication

Maxillofacial Prosthesis- Mould (shell fabrication)

Fixed partial denture (fpd):-**Fabrication of wax pattern for FPD:-**

Fabrication of wax pattern for porcelain fused crowns, pressed ceramic crown, and RPD framework will consume lot of laboratory time and work and it also depends on the skill of the individual who is fabricating .3d printing and fused deposition methods are used for fabrication of wax pattern. The advantage is high production rate. With RP techniques, the dental laboratory can easily reach a production rate of over 150 units per hour, quality control of wax copings, which results in a high precision fit and constant wall thickness, reduced spruing time and reduced finishing work needed on cast copings. The irregularities in wax coping thickness can be avoided, as they usually create extra work for finishing the metal after the cast.⁴

Metal prosthesis fabrication:-

Rapid prototyping technology is used for fabrication of metal prosthesis in fixed partial denture. For fabrication of metal prosthesis selective laser sintering technology is used and fabrication is explained in the above. As the machine can create hundreds of units at a time the cost of each one is relatively low. Laser sintering is a precision, computer controlled process that ensures consistent framework integrity. Here is no possibility of inclusions or defects that are commonly introduced in manual casting processes. Multi-unit cast frameworks can suffer from distortion as they cool. it produces prosthesis with improved marginal integrity.⁵

Zirconia prosthesis fabrication:-

Since the 1980s, research and development of dental CAD/CAM milling systems has been actively pursued worldwide. Recently, commercial dental CAD/CAM milling systems have been successfully introduced for specific

fields such as all-ceramic restorations. These milling systems enabled zirconia ceramics to be used as a standard material for dental prosthetic restorations; however, the disadvantage of this system is the considerable amount of raw material waste, because

The unused portions of the monoblocks must be discarded after milling, and recycling of the excess ceramic material is not feasible. The milling tools are also exposed to heavy abrasion and therefore withstand only short running cycles.

Recently direct inkjet systems are used they reduced laboratory and clinical time, they have high accuracy but the disadvantage is the cost.⁴ A characteristic strength of 763 MPa and a mean fracture toughness of 6.7 MPa $\sqrt{\text{m}}$ were determined on 3D-printed specimens.⁵

Implants:-

Surgical guide fabrication:-

Stereolithography is used for fabrication of surgical guide for implant placement.

The main objective for using SLA models in dentistry is fabrication of surgical drilling templates during dental implant insertion. It is highly accurate, has high mechanical strength and it gives a good surface finish. On the downside it requires post curing, material is costly and requires expensive equipment.⁵

Maxillofacial prosthesis:-

Mould or shell fabrication:-

Over the past decade, RP techniques have been applied successfully to the fabrication of a facial prosthesis. Pattern fabrication via RP has been effective; however, conventional flasking and investing procedures were still needed to make the actual prosthesis. An innovative design and production method (of the negative mold of the facial prosthesis) for casting the actual prosthesis with silicon directly (by using CAD and RP techniques) has been proposed. Instead of fabricating a positive RP pattern of the prosthesis (after the design and fitting stages), the prosthesis computer model is referenced to generate a CAD model of a mold. The mold's cavity then forms the negative profile of the actual prosthesis. The fabricated mold is used to cast the actual prosthesis in polyurethane, medical-grade elastomer, or silastic materials. The use of the mold eliminates conventional flasking and investment procedures, and shortens the prosthesis-making process. In addition, the generated resin mold can be preserved, because the mold is durable and permits multiple pourings. The preservation of the mold is an important step because the silicon prosthesis usually requires a replacement every 2 years (due to discoloration or deterioration of the silicone elastomer). Three-dimensional printing was then used to fabricate the mold for the actual prosthesis with silicone.⁴

Mould for complete denture:-

The process includes establishing a 3D graphic database of artificial teeth for parameterization positioning, getting 3D data of edentulous models and rims in centric relation, exploring a CAD route and developing software for complete dentures, fabricating physical flasks (molds) by 3DP, and finishing the complete denture using a traditional laboratory procedure. Although the system is still in its experimental set-up phase, five complete dentures have been successfully designed and fabricated by this system. On the edentulous plaster models, the dentures were in centric balanced occlusion with a good fit. As a next step, laboratory quantitative tests and clinical experiments should be conducted. To improve the system.⁴ Further studies should be performed to evaluate the quality of complete dentures by applying CAD/CAM technology, to examine the arrangement of artificial teeth using a virtual articulator, and to develop new denture base materials that can be used with RP.⁶

Conclusion:-

Rapid prototyping technology is layer by layer deposition using 3d data and creates physical models. Application of this technology reduced the time and has better outcome. But it also has some limitations such as its expensive and there is wastage of material in few techniques. Further studies have to be conducted to improve the applications of this technology in dentistry

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