RAPID PROTOTYPING -AN INNOVATIVE TOOL IN DIGITAL PROSTHODONTICS - A REVIEW

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ABSTRACT

Emergence of modern era ,provided new designs and perspectives in dentistry.Conventional procedures slowly became digitalised and newer techniques were invented.The CAD/CAM procedures which produced 3D models,through softwares produced prosthesis using subtractive manufacturing process. It had many disadvantages and to overcome it additive manufacturing process were developed. Rapid prototyping is an additive layering technique utilizing different materials and methods. Its application in medicine and dentistry is more nowadays. RP technologies in prosthodontics are used mainly in the fabrication of wax patterns, fabrication of molds and study models for complete denture, fabrication of maxillofacial prosthesis,fabrication of direct metal,fabrication of all ceramic restorations.

Keywords:Rapid prototyping,3D printing,Digital prosthodontics.

INTRODUCTION

Prosthodontics is one of the oldest dental specialities and like others it has seen evolution in favour of the changing needs and current trends.[1] With the advancements in the modern era, conventional procedures are slowly overtaken by digital procedures which provides the advantages of less time consuming,dimensional accuracy and less wastage of materials.

The concept of computer-aided technology (CAD/CAM) which was invented in 1970, aids in the fabrication of dental restorations by milling a block of milling material.[2] First a digital prototype is modelled using CAD and sent to CAM for processing.At this stage,the manufacturing process may be of subtractive and addictive techniques.

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Drawbacks of subtractive techniques used in conventional numeric control machine such as problems in prosthesis fitting, wastage of raw materials, milling tool abrasion led to the usage of additive manufacturing techniques.[3]

Search Strategy:

This paper aims to present a comprehensive literature reviews on various rapid prototyping (RP) methods in dentistry, pertaining to Prosthodontics. Search through PUBMED database and Google scholar search engine was made. The keywords; 'rapid prototyping' , 'digital dentistry' and 'Prosthodontics' were searched in title or abstract of publications; restricted between 2013 and 2021. This review provides the materials, techniques and various applications of Rapid Prototyping in dentistry and in prosthodontics.

Rapid Prototyping :

Rapid prototyping (RP) was introduced in 1980's for the solid objects fabrication obtained from computer aided design for engineering purposes. This method is also called as the "Layered manufacturing","direct digital manufacturing", "three-dimensional printing", "solid free-form fabrication" or "direct digital manufacturing".[4] It can be defined as a method of producing physical prototype in an additive layerwise manner from their CAD model data, CT & MRI scan data and any 3dimensional digitised data without the inclusion of any fixtures specific to the geometry of the model being developed.[5] Therefore it consists of a virtual (modeling and simulating done) and physical phase (fabrication done). RP technology was established in three phases:-[6,7]

1) First prototyping phase: Manual prototyping have been designed by efficient craftsman during this period.

2) Second prototyping phase: During mid 1970s, soft prototype model was emphasized virtually, by precise material using 3D curves.

3) Third prototyping phase: In 1980, layer by layer method have been employed to

develop prototypes after evolution of CAD/CAM technologies.

Applications of Rapid Prototyping :

Introducing rapid prototyping in the biomedical area in 1990 serves several purposes:

A) construction of models to facilitate surgical planning and simulation,

B) complex internal geometries and anatomical landmarks such as neurovascular canals and facial sinuses.[8]

C) improving medical diagnosis,

D) neurosurgery,

E) orthopedics,

F) Shorten surgery time and reduced patient risk.[9,10]

In Dentistry, Rapid Prototyping (RP) technologies were used widely in:[11]

a) Implantology

b) Prosthodontics -fabrication of wax pattern, mold for complete dentures,direct dental metal prosthesis, removable partial denture freamework and clasps ,all ceramic restorations, maxillofacial prosthesis

c) Orthodontics - diagnosis and treatment planning, orthognathic surgery, fabrication of tooth aligner, lingual orthodontics, distraction osteogenesis, fabrication of surgical template for mini implants.

d) Endodontics - diagnosis and treatment planning,,guiding canal, autotransplantation, endodontic training and research

e) Oral surgery

Biomaterials used in Rapid Prototyping :

Many types of different biomaterials were available to be used in RP technologies.[12] They were,

1) Photosensitive resins

2) Various metals and its alloys such as stainless steel, titanium alloys, Cobalt Chromium alloys and others.

3) Advanced bio-ceramic materials (Zirconia, Alumina, porous ceramics, Calcium phosphate-based bio-ceramics)

4) Polycaprolactone (PCL) scaffolds,polypropylene-tricalcium phosphate (PP-TCP), PLGA,starch-

based polymer ,polyetheretherketone-hydroxyapatite (PEEK-HA) PCL-hydroxyapatite (HA), PCL scaffolds. Bone cement: mixture of tetracalcium phosphate (TTCP), Polimethyl methacrylate (PMMA) material and beta – tricalcium phosphate (TCP), polymer calcium phosphate cement composites for both implants and bone substitutes.

In dentistry with these technologies commonly used materials are - wax, plastics, ceramics and metals. .

The material selection depends entirely on the resultant object and RP technique used. Kurth,[13]suggested that based on the state of the prototype material, material accretion technology will be used. Liquid based technology included solidification of the resin upon contact with a laser or the melting and subsequent solidification of prototyping material, solidification of an electro setting fluid. The techniques that uses solid sheets are either bonded using a laser or an adhesive.

Types of Rapid Prototyping technologies :

1. Stereolithography (SLA)
2. Selective laser sintering (SLS)
3. Direct metal laser sintering (DMLS)
4. Fused deposition modelling (FDM)
5. Polyjet 3D printing (PJP)
6. Laminated Object Manufacturing (LOM)
7. Inkjet 3D printing (IJP)
8. Colour-Jet-Printing (CJP)
9. Multi-Jet-Printing (MJP)
10. Electron Beam Melting (EBM)

The common technologies being used in prosthodontics are stereolithography (SLA), inkjet-based system (3DP), selective laser sintering (SLS), and fused deposition modeling (FDM).

Stereolithography (SLA) :

- Stereolithography (SLA) was given by Charles Hull in 1980. It is the first additive manufacturing technology for fabrication of prototypes, models and dental casting patterns.

- most favoured advanced RP system

- The components include a photosensitive liquid resin bath, an ultraviolet (UV) laser to cure the resin and a model-building platform.
- utilizes computer-controlled moving laser beam for building up the required objects from a liquid in layer by layer manner by additive manufacturing or 3D printing data.
- exposing the resin to an UV light, hardening of a thin defined layer occurs and once the resin layer is cured, the platform is immersed within the bath in a calculated distance, and then it is being repeated till the full object is formed.[14]
- In dentistry the current foremost purpose is fabrication of high precison surgical drilling templates during insertion of dental implants, making impressions for reconstructive surgeries and sub-periosteal dental implant surgeries.[17].
- Less availability of raw materials for this technology as it utilizes only light-sensitive polymers[15].
- Advantages are better surface finish than other methods and less raw material wastage.[16]

Inkjet-based system OR 3DP :

- In 3Dimensional Printing system, measured amount of the raw powder is dispersed from the container by a moving piston.
- Then, a roller suppresses the powder located at the top of the fabrication chamber. Following this the multi-channel jetting head will deposit the liquid adhesive in a 2 dimensional pattern onto the powder, bonding and forming a layer of object.
- Next, the piston will distribute and join an another layer of powder. This layer by layer adding process will continue till the development of a complete prototype .
- The unreacted powder which remains at the end undergoes heating process with the fabricated part sound and intact.[18]

Selective Laser Sintering :

- Selective laser sintering (SLS) discovered by Dr. Carl Deckard and Dr. Joe Beaman in 1980.

- In this layers of powder material selected were fused into a 3D model by appropriating a computer-directed laser.
- A roller distributes the powdered material over a cylindrical surface which is built and is spread on top layer wise fashion of the preceding hardened layer and repeated sintering is done.
- To support the newly added layer of powder, the supporting platform maintains one object layer thickness. The surface of this firmly compressed powder is then exposed to a beam of laser. [19]
- Especially in prosthodontics, thermoplastic materials commonly employed in this method includes nylon composite, metallic materials, ceramics, investment casting wax and thermoplastic composites.

Fused Deposition Modeling (FDM) :

- In FDM method,thermoplastic material is used for the fabrication purpose.
- Temperature-controlled FDM extrusion nozzle dome is used in delivering the thermoplastic polymer which is then heated to form a free-flowing semi-liquid.
- The processor controls the motion of the nozzle head which leads the material into place with an ample precision to trace and deposits the raw material in very thin layers onto a subsidiary platform.
- Layer by layer built up of the subject is done and the underlying material solidifies in less than 0.1s after being emitted from the nozzle .
- The supporting structures in the process are used for projecting geometries and are later removed from the completed object.

Direct Metal Laser Sintering (DMLS):

- DMLS technique is used in the fabrication of metal parts with high precision and mechanical strength.
- The metal material is added layer by layer and to fuse powder. From a definite point laser beam is used in the fabrication of prosthesis.[20]

Laminated object manufacturing (LOM):

- Defined sheets of materials were used for fabrication in this method.

- As per the desired cross-section lasers are used to cut the sheet material and adhesives are used to conjoin the layers and created by repeating the steps again.[21]

Applications of RP in prosthodontics :

Rapid Prototyping is widely used in dentistry and mainly in prosthodontics it has wide applications.It is used in the fabrication of wax patterns, mold for complete dentures, Direct Fabrication of Prosthetic Constructions from Metal, 3D Printing of Molds for Metal Casting, molds for maxillofacial prosthesis, fabrication of all ceramic restorations, fabrication of framework and clasps for removable partial denture .

- Fabrication of Wax Patterns :

Wax pattern manufacturing is the first step in the fabrication of prosthesis. In the modern digital era, preparation of wax patterns is done using RP technologies. Traditional lost wax technique is still required after fabrication of wax pattern. Advantages of using RP is many number of wax patterns can be made,fine details and accuracy, and affordable.[22]

- Direct Fabrication of Prosthetic Constructions from Metal:

Direct fabrication of metal prosthesis is done through selective laser sintering/selective laser melting technologies. These technologies are time saving and skips the long preparation process in conventional lost-wax manufacturing. It also exclude the risk of failure in cases with metal parts having complex shapes. Restorations with high precision and intricate geometries and can be made using these.[23]

- Molds for Complete Dentures :

In complete denture fabrication, Rapid Prototyping technologies and their related studies are less. In complete denture, it comprises of 3D graphic record of artificial teeth for positioning, obtaining three-dimensional data of edentulous models and occlusal rims in centric relation, and finishing the

complete denture using conventional laboratory procedure. By applying RP technology trial dentures can also be made from the denture data. [24,25]

- Maxillofacial prosthetics :

Rapid Prototyping technologies are widely used in the fabrication of maxillofacial prosthesis.Defects that are congenital,due to trauma and ablative surgeries are rehabilitated by maxillofacial prosthesis. Complex shapes with undercut areas and internal detail are produced by RP technologies. Fabrication of maxillofacial prosthesis by SLA is done by curing a liquid resin with computer□guided laser. A newer system in the fabrication is the thermoset printer (3D Systems).The type of prosthesis made using these advanced methods are [26]

- Fabrication of obturator

- Fabrication of auricular, nasal prosthesis

- Forming surgical stents for patients with large tumours planned for excision.

- Lead shields in radiotherapy treatment to protect healthy tissue.

- Formation of burn stents, which aids during impression taking procedures.

- All-ceramic restoration fabrication:

For the fabrication of the green-zirconia all-ceramic dental restoration , direct inkjet fabrication process using a slurry micro extrusion process is used. This new method produces restorations with high precision and minimal usage of raw material. It is still in the experimental phase and further studies needed.[27]

- 3D Printing of Molds for Metal Casting:

Ceramic casting molds are generated through an additive printing method with the advanced technologies.Eliminating the need of wax pattern fabrication ,core tooling, wax and core molding, wax assembly, shell dipping and drying, wax-eliminating process is an advantage in using RP in creating metal casting molds.[28]

Conclusion :

Since its invention in 1980 , Rapid Prototyping technology is being used in engineering, medical and dental fields . This

literature review illustrates the application of Rapid Prototyping, in dentistry in general and especially in prosthodontics. Conventional procedures used in the fabrication of prosthesis has disadvantages such as time-consuming, labor-intensive, problems with fit and accuracy, fail to reproduce fine details and complex geometries.With the advances in technologies, these shortcomings have overcome in the fabrication of dental prosthesis .varieties of Rapid Prototyping methods are employed in construction of restorations and each one has its own advantages and limitations.Using 3D, CAD/CAM procedures models were prepared and prosthesis fabrication is done using any one of the methods. With the digital era in progress,many clinicians and laboratories prefer these RP technologies.The limitations of this innovation is high cost, heavy machineries, lack of expertise knowledge and skill.Yet, lot of studies and researches are needed to substantiate the use of Rapid Prototyping in all aspects of dentistry.

CONFLICTS OF INTERESTS :

No conflicts of interest

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