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Rapid Prototyping Prosthodontics: Generative Manufacturing Technique

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ABSTRACT

Rapid prototyping (RP) is an expression that represents a set of additive technologies based on the construction of physical three-dimensional structures, layer by layer, based on its respective digital models. Firstly, the digital model is sliced, and its transversal sections are physically reproduced through automated processes of layer-by-layer construction in raw materials such as powder, solid, or liquid. The RP technologies allow fabrication of these three-dimensional physical structures, known as rapid prototypes, without amendments, with complex geometries, and containing mobile parts that are difficult or even impossible to be obtained by other construction techniques. 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 and surgery, dental implantology as a surgical guide or physical model and Prosthodontics. With advancement in various RP systems, it is possible to benefit from this technique in different dental practices, particularly in implementing dental prostheses for different applications. This review depicted the different laboratory procedures employed in this method and confirmed that RP technique have been substantially feasible in dentistry. RP techniques are increasingly playing an imperative role in prosthodontics and will become one of the mainstream technologies for digital fabrication of dental prostheses in near future.

Keywords: Rapid prototyping, Prosthodontics, Dentistry, Generative Manufacturing Techniques

INTRODUCTION

Prototyping also known as model making is one of the important steps to finalize a product design and aids in conceptualization of a design. A prototype is usually fabricated and tested before the start of full production. Manual prototyping by a skilled craftsman has been an age-old practice for many centuries. The next phase/era of prototyping originated around mid-1970s, when a soft prototype modeled by 3D curves and surfaces could be stressed in virtual environment, simulated and tested with exact material and other properties. Present and the latest trend of prototyping, i.e., Rapid Prototyping (RP) by layer-by-layer material deposition, started during early 1980s with the enormous growth in Computer Aided Design and Manufacturing (CAD/CAM) technologies. Historical development of rapid prototyping and other related technologies is shown in Table-1.[1,2,3,4]

Table-1: Historical development of Rapid Prototyping.

Year of inception	Technology
1770	Mechanization
1946	Early computer
1952	Early Numerical Control (NC) machine tool
1960	Early commercial laser

1961	Early commercial Robot
1963	Early interactive graphics system (early version of Computer Aided Design)
1988	Early commercial Rapid Prototyping system

The frequent RP technologies that are applied in dental practice are stereo lithography (SLA), inkjet-based system (3DP), selective laser sintering (SLS), and fused deposition modeling (FDM). And various materials can be used in these technologies; wax, plastics, ceramics, and metals are frequently and commonly used by several studies in dentistry. After its introduction in the biomedical area, several applications were put forth, mainly for the fabrication of models to ease surgical planning and simulation, in Implantology, neurosurgery, orthopedics, along with oral and maxillofacial prosthesis. In present years, RP is becoming more applicable for dental purposes. The innovative methods in molding materials and forming procedure have improvised the RP techniques so that this technology is no longer adopted only for prototyping; it is used for reproduction of real functional elements. The dental prostheses such as crowns, fixed and removable partial dentures (FPDs and RPDs) and also copings can also be planned and produced with RP techniques. All the faults caused by human skills and intervention in traditional fabrication of dental prosthesis would be eliminated by this latest technique and comparably is time saving as compared to other traditional methods.[3,5,6]

Hence, this literature review made an attempt to describe the evolution of the RP technique in prosthodontic care to ease the technique and improve surgical results and fabrication of maxillofacial prostheses with increasing feasibility of this technique in different dental practice fields.

Definition and concept:

Rapid prototyping can be defined as that procedure in which a physical prototype is fabricated in a layer by layer manner from their CAD models and there is no any human interference or any tools, dies or fixtures specific to the geometry of the model being fabricated. In any industry and/or medicine; two different approaches have been used for the fabrication of physical prototype (model) namely **(a) subtractive and (b) additive**. The subtractive method is usually accomplished by the conventional NC machining, generally milling. The input data for this technique are principally from an optical or contact probe surface digitizer which can only capture the external surface data of the anatomy and not the internal tissue structure of the proposed object. Commonly used to fabricate metallic and/or ceramic crowns in dentistry.[6,7]

Whereas the additive method can produce arbitrarily complex shapes with cavities; which is usually the case in human anatomy structures. The concept behind this approach is called "Layered manufacturing" or "solid free form fabrication," is that a solid 3D CAD model of an object decomposed into cross-sectional layer representations or the captured 3D data set, rapidly slice into cross-sections, and construct layers from the bottom up, bonding one on top of the other, to produce models for applications. The main advantage of this technique over others is the ability of the technique to create minor details such as undercuts, voids, and complex internal geometries (neurovascular canals or sinuses, etc.) in the proposed model.[6,7]

The RP models production for dental restorations models' as well as, medical models', the manufacturing procedure includes: (1) data acquisition, (2) data processing and (3) model fabrication as shown in table-2 below.[4]

Table-2: Steps of RP models production.

CAD-CAM steps	***CAD-CAM system***
Data acquisition	Optical modeling, laser scanning, CT, MRI, digital photographs
Data processing	Digital data is process to obtain a CAD model
Model fabrication	Rapid prototyping, CNC milling

APPLICATIONS IN PROSTHODONTICS

Like in industry and many branches of medicine, rapid prototyping has been also used in dentistry for a wide range including oral and maxillofacial prosthodontics and surgery, in implant placement as a surgical guide or physical model and Prosthodontics.[1,2,3,4,5,]The frequent RP technologies that are applied in dental practice are (I) Stereo lithography (SLA)- It creates three dimensional model by using a computer-controlled moving laser beam in order to build up the required objects from a liquid in a layer by layer manner[8,9], (II) Inkjet-based system (3DP)- The working principle of this RP system is basically similar to the conventional 2D inkjet printer. 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 and shows outstanding performance to produce extremely fine resolution and surface finishes, essentially equivalent to CNC machines [2,7], (III) Selective laser sintering (SLS)- 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)[3,5,10], and (IV) Fused deposition modeling (FDM)- it is RP method where a thermoplastic material is extruded layer by layer from a nozzle, controlled by temperature. FDM is suitable for the fabrication of bone models.[2,7]

With the origin of rapid prototyping technology solid objects of computer models are produced. It is powerful manufacturing method as it can form functional structures in a direct way such as metal parts, and can also be used in nano-/micro- manufacturing and bio manufacturing[11]. The common applications of RP technology in prosthodontics include-

- **Dental prosthesis wax pattern fabrication:** automatic wax-up construction in a new style is possible with RP. Even the traditional lost-wax process is still needed after the fabrication of wax pattern by RP. The process is more affordable than laser melting or sintering direct manufacturing processes, which still remains financially unattainable for most dental laboratories [3,5,7,12,13].
- **Direct dental metal prosthesis fabrication:** brisk fabrication of high-precision metal parts with various resources and shapes without the extensive manual pre- or post-processing steps is possible with selective laser melting (SLM) and selective laser sintering (SLS) technology[3,5,14,15].
- **Dental (facial) prosthesis mold (shell) for metal casting:** Various labor-intensive and time consuming steps of the traditional investment casting technique are eliminated with the use of RP technology. Even the process of design and manufacturing of wax and core tooling, wax and core molding, wax assembly, shell dipping and drying, and wax elimination are also skipped by RP[3,5,14].
- **All-ceramic restoration fabrication:** CAD/RP system is completely efficient in production of all-ceramic dental restorations with high precision, cost competence, and minimum material intake. The fabrication of the green-zirconia all-ceramic dental restoration using a slurry micro extrusion process is done with direct inkjet fabrication RP[3,5,7,16].
- **Mold for complete dentures:** a 3D graphic record of artificial teeth for parameterization positioning, yielding 3D data of edentulous models and rims in centric relation, finding a CAD route and emergence of a software for complete dentures, fabricating physical flasks (molds) by 3DP, and finishing the complete denture using a traditional laboratory procedure is possible with the use of RP[3,5,7,17,18].
- **Mold for facial prosthesis:** mold prepared with RP remove the conventional flasking and investment procedures, and would shorten the process of making the prosthesis and the mold is long-lasting and allows the pouring in multiple times[3,5,19,20].

Advantages of RP Systems[4,21]

- The obvious benefit of rapid prototyping is speed. It is fast and time saving as only 1to 2 days are required in construction and insertion of the prosthesis.
- Early detection and repair of Design defects is possible.
- Tissues are less traumatized and managed properly.
- Accurate Osseous Topography analysis.
- 3D technique made accurate assessment of anatomical landmarks possible like the size of the maxillary sinus in the upper jaw and location of the alveolar nerve in the lower jaw.
- Implants can be located accurately and precisely.
- Confidence of the design integrity is possible with RP technique.
- If primary model is wasted or damaged during fabrication process, digital one can be used.
- lab work due to creation of positive models can be reduced with CAD and RP technique.

Disadvantages of RP Systems [4,21]

- Materials and equipments for RP method are very expensive.
- Undercuts which are not registered by the lenses will be lost, this can be minimized by positioning the patient correctly though it creates an additional undercut.
- Presence of unsupported soft tissue contraindicates the use of RP technique and a two-steps impression may be required to have proper orientation of the soft tissue.

CONCLUSION

This paper provides an overview of RP technology in brief and emphasizes on their ability to shorten the product design and development process. An attempt has been made to include some important factors to be considered before starting part deposition for proper utilization of potentials of RP processes. With advancement in various RP systems, it is possible to benefit from this technique in different dental practices, particularly in implementing dental prostheses for different applications. The limits RP technology include the high cost of the tools, complicated machinery and technique sensitivity.

REFERENCES

[1]. Pandey, P.M., Reddy N.V., Dhande, S.G. (2003a) Slicing Procedures in Layered Manufacturing: A Review, Rapid Prototyping Journal, 9(5), pp. 274-288.
[2]. Azari A, Nikzad S. The evolution of rapid prototyping in dentistry: A review. Rapid Prototyp Jr 2009; 15: 216-225.
[3]. Liu Q, Leu MC, Schmitt SM. Rapid prototyping in dentistry: Technology and application. Int J AdvManufTechnol 2006; 29: 317-35.
[4]. Raja'a M. Mussawia A A, Faridb F, Mohammed T, Shafieid A F. Prosthodontic using Rapid Prototyping. American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS) (2016) Volume 26, No 1, pp 271-285.
[5]. Torabi K,Farjood E, Hamedani S. Rapid Prototyping Technologies and their Applications in Prosthodontics, a Review of Literature. J Dent Shiraz Univ Med Sci., March 2015; 16(1): 1-9.
[6]. Goiato M C, Santos M R et al. Prototyping for Surgical and Prosthetic Treatment. J CraniofacSurg 2011;22: 914Y917.
[7]. Madhav V N V, Daule R. Rapid Prototyping and its Application in Dentistry. Journal of Dental& Allied Sciences 2013;2(2)57-61.
[8]. D'Urso PS, Barker TM, Earwaker WJ, Bruce LJ, Atkinson RL, Lanigan MW, Arvier JF, Effeney DJ. Stereolithographic bio modelling in craniomaxillofacial surgery: a prospective trial. Jr CraniomaxillofacSurg 1999; 27: 30.
[9]. Bhatnagar P, Kaur J, Arora P, Arora V.″Rapid Prototyping in Dentistry – An Update.″ International Journal of Life Sciences, Vol.3,Iss.2, pp.50–3, 2014.
[10]. Gibson I, Cheung LK, Chow SP, Cheung WL, Beh SL, Savalani M, et al. ″The use of rapid prototyping to assist medical applications.″ Rapid Prototyping Journal, Vol.12, Iss.1, pp.53–8,2006.
[11]. Yan Y, Li S, Zhang R, Lin F, Wu R, Lu Q, et al. ″Rapid Prototyping and Manufacturing Technology: Principle, Representative Technics, Applications, and Development Trends″ Tsinghua Science and Technology, Vol.14, Iss.1, pp.1–12, June.2009.
[12]. Wu M, Tinschert J, Augthun M, Wagner I, Schädlich- St- ubenrauch J, Sahm PR, et al. Application of laser measuring, numerical simulation and rapid prototyping to titanium dental castings. Dent Mater 2001; 17: 102-108.
[13]. Williams RJ, Bibb R, Eggbeer D, Collis J. Use of CAD/ CAM technology to fabricate a removable partial denture framework. J Prosthet Dent 2006; 96: 96-99.
[14]. Sun J, Zhang FQ. The application of rapid prototyping in prosthodontics. J Prosthodont 2012; 21: 641-644.
[15]. Ciocca L, Fantini M, De Crescenzio F, Corinaldesi G, Scotti R. Direct metal laser sintering (DMLS) of a customized titanium mesh for prosthetically guided bone regeneration of atrophic maxillary arches. Med BiolEngComput 2011; 49: 1347-1352.
[16]. Wang JW, Shaw LL. Fabrication of functionally graded materials via inkjet color printing. J Am Ceram Soc 2006; 89: 3285-3289.
[17]. Kanazawa M, Inokoshi M, Minakuchi S, Ohbayashi N. Trial of a CAD/CAM system for fabricating complete dentures. Dent Mater J 2011; 30: 93-96.
[18]. Sun Y, Lü P, Wang Y. Study on CAD&RP for removable complete denture. Comput Methods Programs Biomed 2009; 93: 266-272.
[19]. Sykes LM, Parrott AM, Owen CP, Snaddon DR. Applications of rapid prototyping technology in maxillofacial prosthetics. Int J Prosthodont 2004; 17: 454-459.
[20]. Al Mardini M, Ercoli C, Graser GN. A technique to produce a mirror-image wax pattern of an ear using rapid pro-totyping technology. J Prosthet Dent 2005; 94: 195198.
[21]. Sunil Dhaded et al. ″Rapid prototyping in dentistry – a review. ″ Guident, Aug. 2014.