# 3D-PRINTING IN CONTEMPORARY PROSTHODONTIC TREATMENT

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## ABSTRACT

**The purpose of the present paper is to make a review of the applications for 3D-printing in contemporary prosthetic treatment as this modern technology has become widely spread not only in the industry but in medicine and dentistry, too. It is a form of additive manufacturing technology where a three-dimensional object is created by laying down successive layers of material.**

**Keywords:** *3D-printing, rapid prototyping, additive manufacturing of prosthetic constructions*

## INTRODUCTION

The concept of computer-aided design/computer-aided manufacturing (CAD/CAM) of objects was invented long time ago in the 1970s and has already been applied in the field of dentistry for decades for fabrication of dental restorations in prosthodontics. The first step of the process is the creation of a 3D digital model of the future construction which is generated by the CAD. Then the real object is fabricated by the CAM unit. The data for the CAD is obtained either through indirect scanning of a plaster model or through intraoral scanning of the prosthetic field. The direct approach of scanning is a result of the long evolution of this technology and eliminates all the existing disadvantages of impression materials as well as the chance of a laboratory mistake. Digital impressions are highly accurate, dimensionally stable and comfortable for the patient. The communication between the dental office and the laboratory has never been so easy regardless of the distance between them. The whole procedure is reduced to sending just a file. Then a digital prototype of the construction is built and processed to the CAM unit. There are two possibilities for the manufacturing of the real dental restoration in this stage – subtractive and additive technologies. Rapid prototyping (RP) has progressed swiftly in various fields of dentistry as it has the potential to overcome known draw-

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backs of the subtractive techniques such as fit problems, wasting of considerable amount of raw material, excessive abrasion of milling tools, microscopic cracks into the ceramic, limitations of the precision fit of the inside contour which depends on the smallest tool (1,2,3,4,5).

terms that are often used in different science sources are also: "layered manufacturing", "freeform fabrication", "rapid prototyping", "rapid manufacturing" (7,9,10,11,12).

3D printers are machines that produce physical


*Fig. 1. The process of 3D-printing (13)*

The aim of the present paper is to make a review of the applications of 3D-printing technologies in contemporary prosthodontic treatment.

### *ADDITIVE MANUFACTURING*

The term "additive manufacturing" is defined by the American Society for Testing and Materials (ASTM) as: „the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies" (6,7). The "joining" of each new predetermined layer upon the previous layer is based on melting, fusing or a polymerization process. Engineering has invented various technologies for additive manufacturing. Stereo lithography, fused deposition modeling, selective electron beam melting, laser powder forming and inkjet printing are the most used methods in dentistry (8).

For the purpose of layer-by-layer structuring of the real dental restoration, first, the digital image of the object is sliced in the CAD unit by special software. Then the manufacturing of the 3D prosthesis continues with a process almost similar to printing on paper – one layer on top of another. It is the so-called "3D-printing" (1,9) (Fig. 1). Synonymous 3D models from digital data by printing layer by layer. They can make physical models of objects either designed with a CAD program or scanned with a 3D scanner.

Stereo lithography (SLA) is the first additive technology that was created by Charles Hull for manufacturing of prototypes, models and casting patterns (14). The indications for the use of SLA gave the name of the term "rapid prototyping".

### *3D PRINTING IN PROSTHETIC DENTISTRY*

3D printing is a modern technology with various applications in prosthetic dentistry that has developed rapidly during last years as it saves time, manpower and guarantees perfect marginal fit of the fabricated constructions (15).

Very important advantage of the additive technologies concerning prosthetic dentistry, is the possibility to print objects from various materials: polymers, composites, metals and alloys with a dense structure and predetermined surface roughness (8). They allow the manufacturing of complicated geometrical shapes without the need of special adjusting of the CAM unit as well as the use of different mate-

rials in different parts of the same object after controlled conduction (11).

Currently the most frequently applied additive technologies in Prosthetic Dentistry are stereolithography (SLA), inkjet-based system (3DP), selective laser sintering (SLS) and fused deposition modeling (FDM) mainly with wax, metal alloys, resin materials and ceramics (11,16). The innovations and development of material and engineering sciences made the RP technologies more popular for dental purposes not only for prototyping but also for fabrication of real functional objects (17, 18). Due to the great variety of additive manufacturing processes and materials 3D printing is applied for the production of different constructions not only in prosthodontics but also in many other fields of dentistry – surgery, oral implantology, orthodontics, etc. (Fig. 2).

ic treatment while reducing the intraoral time for the patients (22).

### *Fabrication of Wax Patterns for Prosthetic Constructions*

The mManufacturing of wax pattern is the first step in the process of fabrication of a dental prosthesis. The RP technologies had made possible automatic build- up of numbers of wax patterns for different dental constructions by structuring them up layer by layer. The Nnext step remains the traditional lost-wax procedure (Fig. 3). Stereolithography is also feasible for the manufacturing of custom trays, provisional crowns and bridges (Fig. 4), removable partial and complete dentures, surgical guides, preventive splits and appliaences, etc. for the purpose of prosthetic dentistry.

*Fig. 2. Maxillofacial prosthesis and complete denture fabricated by additive manufacturing (13)*

The feasibility of 3D printing in prosthodontics has been increasing in the last years (17,19,20). Rapid prototyping can be implemented for the fabrication of implant surgical guides, frameworks for fixed and removable partial dentures, wax patterns for the dental prosthesis, zirconia prosthesis and molds for metal castings, maxillofacial prosthesis and complete denture (21). It helps a lot during the planning and developing of a certain construction in prosthet-

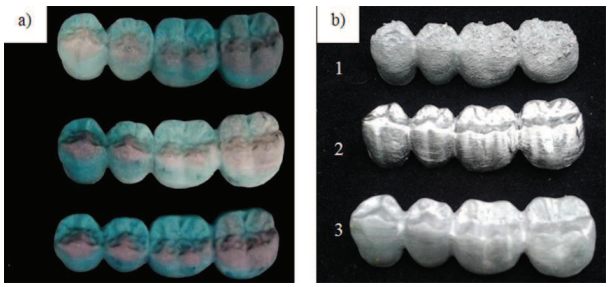


*Fig. 3. Wax patterns, produced by 3D printing – a) and 4-part bridges produced by SLM of Co-Cr alloy – b). (1 – as received SLM bridge, 2 – after mechanical treatment, 3 – after sand-blasting)*

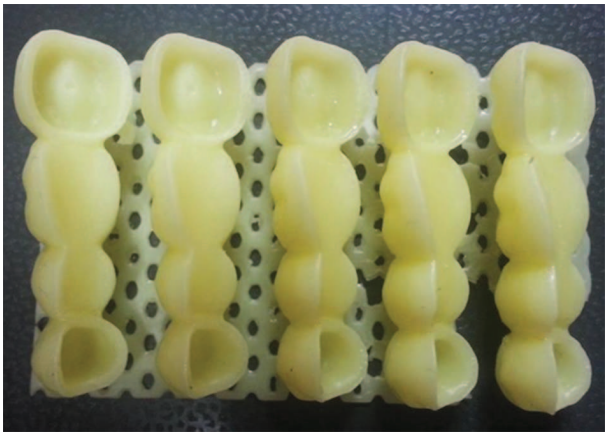

*Fig. 4. Polymer temporary bridges, produced by stereolytography.*

### *Direct Fabrication of Prosthetic Constructions from Metal*

Direct fabrication of metal prosthesis is already possible through selective laser sintering/selective laser melting technologies (SLS/SLM) (Fig. 3). The new technologies skip the long preparation process in conventional lost-wax manufacturing and respectively eliminate the risk of failure especially in cases with metal parts with complex shape as are the prosthetic constructions.

### *3D Printing of Molds for Metal Casting*

Ceramic casting molds are fabricated trough an incremental printing method (23) without the need of manufacturing wax pattern and all of the following steps in the wax-eliminating process (21,24).

### *3D Printing of Molds for Facial Prosthesis*

Rapid prototyping aided manufacturing of facial prosthesis molds is alternative to the conventional flasking and investment procedures. This modern trend in the fabrication of facial prosthesis shortens the whole process and allows multiple pourings from a single mold (25).

### *3D Printing of Molds for Complete Dentures*

Advanced manufacturing technologies are used in the field of complete dentures mainly to fabricate a physical mold of the denture through a CAD process. 3D graphic records of the artificial teeth as well as 3D data of the edentulous rims and their centric relation are needed for the software. Since the mold is ready the complete denture undergoes the traditional manufacturing process to be ready for the dental office (21,24,26).

### *Fabrication of All-Ceramic Restorations*

The direct inkjet advanced technology can be implemented for fabrication of green-zirconia all-ceramic restorations (27). The 3D printing of all-ceramic restorations is still an object of science researches and experiments.

## CONCLUSION

There is no doubt that in the future additive technologies will replace many stages and even the whole process of the conventional manual making of dentures and the specialists will need to control and participate in the CAD/CAM process only in the visualization part. The main advantages of the RP manufacturing of dental restorations are the significant decrease of the time needed for production cycle and the cost of the final restoration. It also favors a collaboration between the dental laboratory and the dental office. Last but not least, there is the important fact that advanced technologies eliminate the risk of dimensional changes of the impressions and casts because they skip these procedures – the prosthetic field can just be scanned and the model directly printed without any disruption of the tissues. The dental laboratory does not need more square meters now because everything is stored simply in the computer hard disk.

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## REFERENCES

1. Cohen A. Vacuum forming applications using rapid prototyping technology, Object Geometries: White Paper; 2008. available at: http://www.tritech3d.co.uk/images/ contentitems/63_1_1.pdf
2. Wang JW, Shaw LL. Fabrication of functionally graded materials via inkjet color printing, J Am Ceram Soc 2006; 89: 3285-3289
3. Tay BY, Evans JRG, Edirisinghe MJ. Solid Freeform Fabrication of Ceramics, Int Mater Rev 2003; 48: 341- 370
4. Özkol E, Ebert J, Uibel K, Wätjen AM, Telle R. Development of high solid content aqueous 3Y-TZP suspensions for direct inkjet printing using a thermal inkjet printer, J Eur Ceram Soc 2009; 29: 403-409

**5.** Noguera R, Lejeune M, Chartier T. 3D fine scale ceramic components formed by ink-jet prototyping process, J Eur Ceram Soc 2005; 25: 2055-2059

**6.** Van Noort R. The future of dental devices is digital, Dent Mater. 2012; 28:3-12. [PubMed]

**7.** Dovbish VM, Zabednov PV, Zlenko MA. Additivnie tehnologii I izdelia iz metala, 57p.[in Russian]

**8.** Dikova T, Dzhendov D, Simov M, Katreva-Bozukova I, Angelova S, Pavlova D, Abadzhiev M, Tonchev T. Modern trends in the development of the technologies for production of dental constructions, Journal of IMAB - Annual Proceeding (Scientific Papers) 2015, vol. 21, issue 4,pp 974-981

**9.** Thomas D. The Development of Design Rules for Selective Laser Melting [PhD thesis]. [Cardiff]: University of Wales Institute; 2009. 318 p

**10.** Gosawi S, Kumar S, Lakhyani R, Bacha S, Wangadargi S. Lasers in prosthodontics - a review, Journal of Evolution of Medical and Dental Sciences. 2012 Oct;1(4):624-634

**11.** Andonović V, Vrtanoski G. Growing rapid prototyping as a technology in dental medicine, Mech Eng Sci J 2010; 29: 31-39

**12.** Weiss LE. "Process overview. Rapid prototyping in Europe and Japan", Loyola College of Maryland, Baltimore, MD. Available at: http://www.wtec.org/loyola/rp/a_bios. htm#LWeiss

**13.** Luthra V, Sharma V. 3D Printing, CSE – 5D, ITM University, ppt. available at www.slideshare.net

**14.** Hull CW. Apparatus for production of three dimensional objects by stereolithography, U.S. patent 4575330, U.S. Patent Office, March 11, 1986

**15.** Beijing Da Xue Xue Bao., Liu XZ, Lu PJ, Wang Y. Research progress of dental machinable materials, 2008 Dec 18;40(6):654-7. [Article in Chinese]

**16.** Azari A, Nikzad S. The evolution of rapid prototyping in dentistry: a review, Rapid Prototyping J 2009; 15: 216-225

**17.** Sun J, Zhang FQ. The application of rapid prototyping in prosthodontics, J Prosthodont 2012; 21: 641-644

**18.** Goiato MC, Santos MR, Pesqueira AA, Moreno A, dos Santos DM, Haddad MF. Prototyping for surgical and prosthetic treatment, J Craniofac Surg 2011; 22: 914-917

**19.** Jeng JY, Chang KY, Dong DR, Shih HS.Tooth crown fabrication using reverse engineering technology and model maker rapid prototyping system, Rapid Prototyp J 2000; 6: 136-145

**20.** Bibb R, Eggbeer D, Williams R. Rapid manufacture of removable partial denture frameworks. Rapid Prototyping J 2006; 12: 95-99

**21.** Torabi K., Farjood E., Hamedani Sh. Rapid Prototyping Technologies and their Applications in Prosthodontics, a Review of Literature, J Dent Shiraz Univ Med Sci., March 2015; 16(1): 1-9

**22.** Han J, Wang Y, Lü P. A preliminary report of designing removable partial denture frameworks using a specifically developed software package, Int J Prosthodont 2010; 23: 370-375

**23.** Bassoli E, Gatto A, Luliano L, Violentte MG.3D printing technique applied to rapid casting, Rapid Prototyping J 2007; 13: 148-155

**24.** Sun J, Zhang FQ. The application of rapid prototyping in prosthodontics, J Prosthodont 2012; 21: 641-644

**25.** Cheah CM, Chua CK, Tan KH. Integration of laser surface digitizing with CAD/CAM techniques for developing facial prostheses. Part 2: Development of molding techniques for casting prosthetic parts, Int J Prosthodont 2003; 16: 543-548

**26.** Sun Y, Lü P, Wang Y. Study on CAD&RP for removable complete denture, Comput Methods Programs Biomed 2009; 93: 266-272