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A COMPREHENSIVE REVIEW

The Advancement of 3D Printed Metals in Prosthodontics: A Comprehensive Review

J.Brintha Jei[a], B.Muthukumar[b]

ABSTRACT

The integration of three-dimensional (3D) printing technologies and prosthodontics have attained significant advancements in the fabrication of dental prosthesis. Due to excellent precision, biocompatibility and mechanical properties 3D metals emerged as a promising option in restorations. 3D printed metal prostheses provides good accuracy and customization, this allows for patient-specific designs by enhancing comfort, fit, longevity, osseointegration, stability and functionality. The additive manufacturing process in prosthodontists gives greater options in design modifications and improvements. Cobalt-chromium alloys and titanium are the commonly used metals in prosthodontic procedures like crowns, bridges and implants. It also reduces patient appointments and waiting time by optimising prosthetic outcomes. Overall, the integration of 3D printed metals in prosthodontics encounters a significant paradigm shift by providing a new era of precise, personalized, precise, and patient-centric prosthodontic solutions.

Key Word: 3D printing, metals, prosthodontics, dental prostheses, additive manufacturing

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INTRODUCTION

Prosthodontics, a specialized branch of dentistry which focus on the restoration and replacement of missing or lost teeth and associated oral structures. 3D printing, also known as additive manufacturing creates three-dimensional objects layer by layer from digital models. In dentistry, this technology can enable the fabrication of customized prostheses with precision and accuracy. Thus it have made it increasingly popular among prosthodontist for various restorations ranging from fabrication of crown and bridge to implant dentistry. In recent years 3D printing technology in prosthodontics has included the use of metals like titanium, cobalt-chrome, and stainless steel for the fabrication of dental prostheses[1].

These metals provide various advantages over traditional materials which includes high strength, durability and biocompatibility[2]. Additive manufacturing is commonly known as 3D printing which create three-dimensional objects by means of layering materials based on the created digital model. In additive manufacturing material will be added layer by layer until the final prosthesis is formed. This process offers several advantages, including increased design flexibility reduced waste, and the ability to create complex geometries that are difficult or impossible to achieve with traditional methods[3]. The importance and scope of 3D printed metals in prosthodontics are significant.

[a] Associate professor, Department of Prosthodontics, SRM Dental college, Ramapuram, Chennai

[b] Professor and Head, Department of Prosthodontics, SRM Dental college, Ramapuram, Chennai

These materials provide dentists and prosthodontists with greater flexibility in designing and fabricating prosthetic devices tailored to each patient's specific needs. From crowns and bridges to removable partial dentures and dental implants, 3D printed metal prostheses offer a precise fit and optimal functionality, enhancing patient comfort and satisfaction. Moreover, the digital workflow associated with 3D printing reduces production time and costs while ensuring consistency and accuracy in the final product.

TYPES OF 3D PRINTING TECHNIQUES IN PROSTHODONTICS

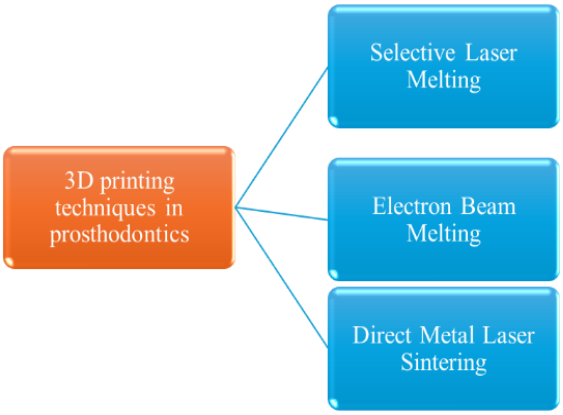

Figure.1: 3D Printing techniques

1. Selective Laser Melting (SLM): It is a high-powered laser which selectively melts and fuses powdered alloy or metal particles together layer by layer based on the specific digital model. This technique is commonly used in the fabrication of crowns, bridges and implants. It is suitable for cobalt chromium alloys, titanium and stainless steel.
2. Direct Metal Laser Sintering (DMLS): This additive manufacturing technique utilizes Low temperature and allows sintering rather than completely melting the metal powder. It can produce prosthesis with good surface finish and accuracy. It is commonly used in prosthodontics for making medium size prosthesis like implant-supported prostheses and crowns and bridges[4,5].
3. Electron Beam Melting (EBM): It melt metal powder by electron beam under high vacuum environment. It is comparatively faster than SLM due to its high energy electron beam. It can produce prosthetic restorations with excellent mechanical properties, especially in high temperature applications.This technique is mainly suited for fabricating complex metal structures and titanium-based dental implants with high precision. EBM can provide uniform distribution of thermal field and can produce restoration with reduced surface roughness.

Each technology has its own limitations and advantages. EBM and SLM are suitable for producing prosthesis with good mechanical properties and DMLS can be used to fabricate prosthetic restorations with excellent surface finish and good dimensional accuracy.

COMPARISON BETWEEN TRADITIONAL FABRICATION METHODS AND 3D PRINTING

Sl.no	Traditional Fabrication Methods	3D Printing
1	Require manual labour and skilled craftsmanship	It requires automated processes
2	Limited design flexibility, especially for complex geometries	Greater design freedom, allowing for complex geometries and
3	Longer production times	Reduced production time due to automated processes
4	Higher material wastage	Minimal material wastage as it uses only required amount of material
5	Limited customization options	Wide range of customization enabled by digital storage and replication of designs
6	Higher costs for small-scale production	Cost-effective for small-scale or custom production runs

Table 1: Comparison between traditional and 3D printing

TYPES OF 3D PRINTED METALS USED IN PROSTHODONTICS

1. Titanium and its Alloys:Titanium alloys exhibit excellent mechanical properties like good fatigue strength and low modulus of elasticity, which is beneficial for dental implants. It has superior biocompatibility and thus it reduce the risk of allergic reactions and also promotes osseointegration between the bone and implant surface. They are lighter in weight and are commonly used in fabricating implants, abutments and frameworks for removable partial dentures. They also provide long term stability and reduce the burden on the patient.

2. Cobalt-Chromium Alloys:It is known for their high strength, corrosion resistance and hardness. They exhibit significant wear resistance and it can withstand high temperature. It has excellent mechanical properties like high tensile strength and fatigue resistance. This makes it suitable for dental prosthesis subjected to high wear and stress. They are commonly used in for fabricating dental crowns, bridges and removable partial denture frameworks[6,7].
3. Stainless Steel:Stainless steel possess moderate strength and corrosion resistance but it is not as biocompatible as titanium or cobalt-chromium alloys and is commonly used for temporary or provisional restorations. It is also cost-effective compared to other metal alloys[8-12].
4. Tantalum :It is a newer material, with excellent osseointegration and biocompatibility properties. But it is rarely used in making dental implants due to its limited availability and high cost[13].
5. Gold alloys:It is less commonly used due to its cost, but occasionally used for making dental prosthesis due to its biocompatibility

INFLUENCE OF 3D PRINTING ON THE PROPERTIES OF 3D METALS

1. Titanium (Ti) alloys.3D printing involves in fabrication of critical designs and porous optimized internal structures of titanium implants. This helps to produce stronger implants with lighter weight. It also enhances the integrity with the surrounding tissues, perfect fitting and superlative functionality.
2. Cobalt-Chromium (Co-Cr) alloys. 3D printing retains the properties of this alloy by controlling the porosity of Co-Cr structures and thus it enhances the osseointegration and also it improves the resistance to wear. Complex prosthetic restorations can be fabricated by less wastage when compared to traditional casting method. Thus making the alloy environmental friendly
3. Stainless Steel (SS)This is a high corrosion resistant metal, this property is further enhanced by 3D printing by optimising the microstructure and precisely controlling the surface texture and roughness. This has enhanced the biocompatibility of SS and reduced the adhesion of microorganisms.
4. Tantalum.The biocompatibility and osseointegration properties of tantalum is enhanced by the porous structure created by 3D printing, which promotes integration with surrounding tissue and bone ingrowth. Additive manufacturing also provides precise control over the density of tantalum implants and enhance the biological response and mechanical properties. Thus it enhances the optimal fit and function of tantalum implants based on patient specification.
5. Gold alloys.3D printing has enhanced the biocompatibility property of gold and helps to fabricate prosthesis with complex designs and precise fit. It also reduces the amount of material wastage in the fabrication process.

APPLICATIONS OF 3D PRINTED METALS IN PROSTHODONTICS

1. 3D printing helps to create complicated implant abutment designs based on specific patient needs including complex geometries[14].
2. It can fabricate bars and attachments for implant supported prosthesis to ensure longevity and stability.
3. Creation of highly accurate, durable, light weight removable partial denture frameworks.
4. Quick fabrication of provisional metal fixed restoration for patients who require immediate restoration of prepared teeth.
5. Fabrication of metal crown and bridges with precise fit and complex designs with perfect fit and reduces the need for adjustments[15-17].
6. 3D printed surgical guides and templates enable accurate placement of dental implants and other surgical procedures and reduces the risk of errors, minimise patient discomfort and shorted operating time.
7. It helps to create instruments like impression trays based on patient's specific anatomy.

COMPARISON OF 3D PRINTING WITH CASTING AND MILLING

Sl no	3D Printing (Additive Manufacturing)	Casting	Milling (Subtractive Manufacturing)
1	Layer by layer formation of prosthesis from digital designs	Molten metal is poured into the mould space and is allowed to solidify	Removes material from solid block using rotating cutting tools.
2	Complex structures can be created easily without additional instruments.	Can produce complex structures but challenging due to the mould limitations.	Complex structures preparation is limited in the internal surface
3	Customization and prototyping is highly possible	Least possible	Prototyping and customization is possible
4	Minimal material wastage	More wastage of material	More material wastage
5	Limited strength when compared to cast and milled parts. SLM and EBM can produce restorations with notable high strength . But it depends on • Print orientation • Direction of loading • Post processing treatment • Adhesion of layers.	Excellent strength	Excellent strength
6	Large restoration requires more time to fabricate	Can produce large restorations with excellent properties.	Large restoration requires more time compared to casting

ADVANTAGES OF 3D PRINTED METALS IN PROSTHODONTICS

1. 3D printing provide precise fabrication of prosthesis with accurate fit and perfect dimensions by integrating digital workflows from digital scanning.
2. Customization of the dental prosthesis based on patient oral anatomy enhance the comfort and satisfaction of the patient.
3. 3D printed metals used in prosthodontics like titanium alloys has excellent mechanical properties and biocompatibility that makes the prosthesis durable and wear resistance[12].
4. Traditional methods is of time-consuming and costly due to the need for extensive manual labour and machining but 3D printing line up the fabrication process by removing many of these steps and results in reduced production time and lower costs[18].
5. 3D printing can create prosthesis with complex geometries and designs which is not possible with traditional methods.
6. It allows for the fabrication of aesthetically pleasing and functional prosthesis.
7. It can be used to fabricate prototype and prosthetic models for patient education and treatment planning

LIMITATIONS

1. Selection of suitable materials for 3D metal printing is critical.
2. To Achieve the desired surface finish directly from the 3D printing process can be challenging task.
3. Extensive post-processing is required to achieve the desired surface property.
4. Any variability in printing conditions can cause inconsistencies this can compromise the function of dental prosthesis
5. The initial investment for materials, equipment and training can be significant.

CONCLUSION

In prosthodontics 3D printed metals has marked a crucial advancement. This is due to the precision, customization and efficiency of additive manufacturing technologies in fabricating dental prostheses. This has drastically improved the clinical outcomes, reduced the treatment costs, streamlined the workflows and provides accessibility to advanced prosthetic solutions for patients worldwide.

REFERENCES

1. Kritika Diwan, Manu Rathee, Sarthak Singh Tomar, Sandeep Singh, Divakar S,Sujata Chahal. Applications of 3D Printing in Prosthodontics: A Review . A Journal of Clinical Dentistry Healtalk. 2023; 15(04), 21–24.
2. Kharge AS, Madhav VNV, Nalavde S, Attal P. 3-D Printing materials in Prosthodontics: A Review. J Prosthodont Dent Mater 2023;4 (1):11-17.
3. Schweiger J, Edelhoff D, Güth JF. 3D Printing in Digital Prosthetic Dentistry: An Overview of Recent Developments in Additive Manufacturing. J Clin Med. 2021;10(9):2010.

4. Katkar RA, Taft RM, Grant GT. 3D volume rendering and 3D printing (additive manufacturing) Dent Clin North Am. 2018;62:393–402
5. Chander, N. Gopi. An overview on 3D printing in prosthodontics. The Journal of Indian Prosthodontic Society. 2020;20(2): 121-122.
6. Jokusch J., Öczan M. Additive manufacturing of dental polymers: An overview on processes, materials and applications. Dent. Mater. J. 2020;39:345–354.
7. Barazanchi A, Li KC, Al-Amleh B, Lyons K, Waddell JN. Mechanical Properties of Laser-Sintered 3D-Printed Cobalt Chromium and Soft-Milled Cobalt Chromium. Prosthesis. 2020; 2(4):313-320.
8. Balestra D, Lowther M, Goracci C, Mandurino M, Cortili S, Paolone G, Louca C, Vichi A. 3D Printed Materials for Permanent Restorations in Indirect Restorative and Prosthetic Dentistry: A Critical Review of the Literature. Materials. 2024; 17(6):1380.
9. Alharbi N, Wismeijer D, Osman RB. Additive manufacturing techniques in prosthodontics: Where do we currently stand? A critical review Int J Prosthodont. 2017;30:474–84
10. Corbani K, Hardan L, Eid R, et al. Fracture Resistance of Three-unit Fixed Dental Prostheses Fabricated with Milled and 3D Printed Composite-based Materials. J Contemp Dent Pract 2021;22(9):985–990.
11. Bora, Pranit V. "Characterization of materials used for 3D printing dental crowns and hybrid prostheses." Journal of Esthetic and Restorative Dentistry. 2024; 36(1): 220-230.
12. Leban, Mirjam Bajt, et al. "Differences between 3-D printed and traditionally milled CoCr dental alloy from casted block in oral environment." Electrochimica acta.2023; 445: 142066.
13. Mohsan AUH, Wei D. Advancements in Additive Manufacturing of Tantalum via the Laser Powder Bed Fusion (PBF-LB/M): A Comprehensive Review. Materials. 2023; 16(19):6419.
14. Yang, Y.; Yang, Z.; Lin, W.-S.; Chen, L.; Tan, J. Digital Duplication and 3D Printing for Implant Overdenture Fabrication. J. Prosthodont. 2021, 30, 139–142.
15. Revilla-León, M.; Methani, M.M.; Morton, D.; Zandinejad, A. Internal and Marginal Discrepancies Associated with Stereolithography (SLA) Additively Manufactured Zirconia Crowns. J. Prosthet. Dent. 2020, 124, 730–737.
16. Alifui-Segbaya F., Williams R.J., George R. Additive manufacturing: A novel method for fabricating cobalt-chromium removable partial denture frameworks. Eur. J. Prosthodont Restor. Dent. 2017;25:73–78.
17. Bae S, Hong M-H, Lee H, Lee C-H, Hong M, Lee J, Lee D-H. Reliability of Metal 3D Printing with Respect to the Marginal Fit of Fixed Dental Prostheses: A Systematic Review and Meta-Analysis. Materials. 2020; 13(21):4781
18. Tregermann I., Renne W., Kelly A., Wilson D. Evaluation of removable partial denture frameworks fabricated using 3 different techniques. J. Prosthet. Dent. 2019;122:390–395.

Corresponding Author: Dr.J.Brintha Jei, Associate professor, Department of Prosthodontics, SRM Dental college, Ramapuram, Chennai.
E-mail: brinthajei@yahoo.co.in , Ph.No.: +91