International Journal For Research In Health Sciences And Nursing
ISSN (Online): 2208-2190
Volume 11 Issue 01 March 2025

DOI:

REVOLUTIONIZING PROSTHODONTICS: THE ROLE OF 3D PRINTING IN MODERN DENTAL REHABILITATION

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Abstract:
In today's digital era, 3D printing, also known as rapid prototyping or additive manufacturing, has become common in dentistry, particularly prosthodontics. This technology creates objects layer by layer using computer-aided designs and manufacturing or advanced imaging techniques. Traditional methods like lost wax technique for prosthesis fabrication are labor-intensive and technique-sensitive, leading to increased adoption of 3D printing and CAD/CAM technologies. 3D printing's history dates back to the 1980s, pioneered by Charles W. Hull for rapid prototyping. With patent expirations and technological advances, 3D printing expanded into various applications, including dentistry, becoming more affordable and capable of handling diverse materials.

Keywords: *3D printing, complete dentures, implant abutments, provisional restorations, metal printing, ceramic printing, removable partial denture, splints.*

Introduction:

In today's era of digitalization, Three-Dimensional (3D) printing, also known as rapid prototyping (RP) or additive manufacturing (AM), has assumed a commonplace in dentistry especially prosthodontics. 3D printing entails physically adding material layer by layer to create an object or structure, employing computer-aided designs and computer-aided manufacturing (CAD/CAM) technology, or utilizing advanced imaging and scanning techniques.(1) The traditional method of lost wax technique for fabrication of prosthesis is not only technique sensitive but also labour intensive. (2) Increase in patient's expectations such as time constraints and comfortable experience has also encouraged many dental practitioners to utilize 3D printing and CAD CAM technologies. (3)

History of 3-D printing:

It was as early as 1980s when the first units of then known as additive manufacturing. Charles W. Hull is considered as the pioneer of 3D printing. (4) However, back then, 3D printers were used only for rapid prototyping. Nevertheless, in the subsequent years, the technology experienced rapid advancements. This progress occurred after the patent for the fused deposition modeling (FDM) process expired. (5) In 2009, 3D printers started making significant strides in the consumer sector, and this trend extended to the dental industry as well. The printers became more compact and affordable, leading to changes in their applications. They could now print various materials, such as plastics, metals, ceramics, and even human tissue. Rapid-prototyping processes were categorized based on the types of materials utilized, including plastics, metals, or powder. (2)

Applications of 3-D printing in prosthodontics:

3D printing, also known as additive manufacturing, has gained significant traction across all disciplines of dentistry, including prosthodontics. The integration of 3D printing in prosthodontics has revolutionized the workflow for prosthesis fabrication. This innovative approach offers several advantages, such as reducing assembly steps, eliminating laborious manual laboratory processes, and presenting the potential for cost-saving models through digital design and automated quality control. (6)

The applications of 3D printing in prosthodontics encompass various specialties, including complete denture, fixed dental prosthesis, implant dentistry, and maxillofacial prosthesis fabrication, each progressing at its own pace. As 3D printing reshapes the landscape of prosthodontic practice, dental practitioners must acquaint themselves with the specific techniques, mechanics, and materials associated with 3D printing for each type of application within the discipline. (7)

This article provides an overview of the numerous applications and workflows of 3D printing in prosthodontics. A comparison of 3D printing outcomes with conventional and CAD/CAM procedures will also be presented to highlight the current status and identify areas for further improvement. (8)

Evolution and Recent advances of 3D printing technology:

With the advent of technology, 3D printing has also seen strides in development. The model developed by Charles Hull involved successive printing of polymer in a layered fashion. Fabrication of surgical guides for implants, (9) obturators for cleft patients, (10) prosthesis duplication, (11) fabrication of surgical stents (12) are some of the common applications of 3D printing. Not long ago, the 3D printing technologies were limited to industries with large manufacturers due to substantial capital investments needs. Nevertheless, recently many printers have become affordable to be used by dental laboratories. (2) In the following paragraphs, the stepwise evolution of materials and methods of 3D printing and the recent advances are discussed:

1. Laser sintering:

Additive manufacturing has been successfully used in processing of non-precious alloys since past two decades. (13) Laser sintering is a new method of manufacturing CoCr crowns with promising results. (14) After the actual build-up, the post processing can be optimised. A number of units can be positioned on the same platform which makes the process cost effective also. In a study it was found that outcome of single unit metal ceramic crowns fabricated using laser sintering technology gives promising results. (15) In other experimental studies, the mechanical properties of laser sintered crowns were found to be at par with cast restorations. (16,17)The marginal fit of laser sintered crowns were superior to cast restorations. (18,19) A recent advancement known as Hybrid manufacturing involves the combination of additive and subtractive steps to attain dual benefit of efficacy of additive manufacturing and precision of milling and has produced exceptional results of surface finish, accurate fit and being economical . (20,21)

2. 3D printing and polymers:

In dentistry currently, broadly two processes are involved in 3d printing i.e. Stereolithography by means of laser source and digital light processing by means of mask exposure process. (22–24) The first STL printer was patented by Charles Hull in 1980s. However, their working was very complicated and these printers were expensive. Recently, these printers are made quite economical. Interestingly, DLP printers use projection technology from Texas Instruments instead, where short-wave light (currently used wavelengths: 380 nm and 405 nm) is guided through a digital micromirror device (DMD) that constitutes the core of the DLP technology. (25,26) The resolution of DLP printers can be increased by ways. Using a DMD chip with higher resolution (27), Two DLP projectors with HD resolution connected in parallel, (28) Moving DLP projectors, (29) Prodways MovingLight technology (30). Material jetting means applying the material directly on the build platform and curing it in a stepwise fashion. (31–33)

3. *Ceramic 3D printing*

All ceramic material scan also be 3D printed now using direct or indirect methods. Numerous adapted 3D printing techniques, stemming from Selective Laser Melting (SLM), have demonstrated their ability to manufacture ceramic components. Examples of these methods include slurry-based SLM and laser-engineered net shaping (LENS). (34,35) Laser micro sintering(LMS) is a method by which the surface roughness of cremains is improved. (36)

Although significant advancements have been achieved in the selection of viable ceramic materials, as well as in the optimization of processing parameters and post-processing, challenges persist, limiting the broader adoption of 3D printing in ceramic fabrication. (37)

Conclusion:

The integration of 3D printing in prosthodontics has revolutionized the workflow, offering benefits like reduced assembly steps and automated quality control. It finds applications in complete denture, fixed dental prosthesis, implant dentistry, and maxillofacial prosthesis fabrication. Dental practitioners must familiarize themselves with the specific techniques and materials for each application. Over time, 3D printing has made significant progress, being used for non-precious alloys, CoCr crowns, and polymers like Stereolithography and digital light processing. Ceramic 3D printing, through methods like Selective Laser Melting and slurry-based SLM, is advancing, though challenges remain in broader adoption for ceramic fabrication.

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