3D PRINTING IN PROSTHODONTICS & RECENT TRENDS IN ADDITIVE MANUFACTURING

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Abstract

Popular media frequently portrays 3D printing as a commonly used technique for the fabrication of dental prosthesis. This article seeks to demonstrate, using true facts, how far 3D printing can be used in dental laboratories and clinics today. It seeks to provide a rational assessment of current applications of 3D printing technology in the context of dental restorations. Furthermore, the article discusses future perspectives and assesses the continued sustainability of traditional dental laboratory services and manufacturing procedures. It also demonstrates what skill is required for digital additive manufacture of dental restorations.

Keywords: *3D Printing; Digital One-Piece Casting; Multi-Material 3D Printing; Graphic 3D Models ; Digital Pressing Technology; Hybrid Production*

Introduction

As with any other field, fundamental shifts in society are also having an impact on dental technology. One of these shifts is the scarcity of competent labor; the number of skilled dental trainees is steadily declining [1], despite the fact that the demand for dental prostheses is still high because of shifting demographics [2].

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The manufacture of digital dental products is developing at an astonishing rate.

While additive technologies, such as 3D printing, are becoming more and more popular, subtractive processes have historically produced high levels of productivity and fit accuracy. Combinations of various production techniques, like digital design and 3D printing combined with analog ceramic pressing or laser sintering combined with CNC machining, show the great potential [3,4]. An increasing number of dental laboratories are already adept at striking a balance between digitalization and craftsmanship, tradition and disruption, and current values and required adjustments. Through the use of computer-aided design, or CAD, the dental technician generates a digital data set before designing a three-dimensional object. The data is then sent to a 3D printer, which turns it into a tangible product. Additive printing is a fundamental component of digital dentistry because of this customization option as well as the quicker, easier, or even less expensive availability of digitally created things [5].

History of 3D Printing

Early in the 1980s, the first industrial-level additive manufacturing (also known as 3D printing) machines were released onto the market. S. Scott Crump, the creator of Stratasys, Hans J. Langer and Hans Steinbichler, the founders of EOS,and Charles W. Hull, the founder of 3D Systems, are among the pioneers of 3D printing. Charles W. Hull received the first 3D printer patent in 1986 [6]. Rapid prototyping was the primary use of 3D printers at the time.

Nonetheless, in the years that followed, technology developed quickly. After the fused deposition modeling (FDM) technique patent [7] expired in 2009, 3D printers started to gain significant traction in the consumer market. In the end, the dental industry adopted this dynamic. The domains of use for printing devices evolved as they got smaller and less expensive. Plastics, metal, ceramics, and even human tissue are now among the materials that can be printed. The materials that are employed in rapid prototyping procedures can be divided into three categories: metals, polymers, and powder.

Classification of Additive CAD/CAM-Based Manufacturing

According to the EN ISO/ASTM 52,900 terminology standard, an AM process is the "Process of joining materials to make objects from 3D model data, usually layer by layer, as opposed to subtractive manufacturing methods" [8]. EN ISO 17296-2 describes the process fundamentals of additive manufacturing.

It also offers a summary of the current process categories; however, this summary can never be exhaustive due to the continual evolution of novel technologies.

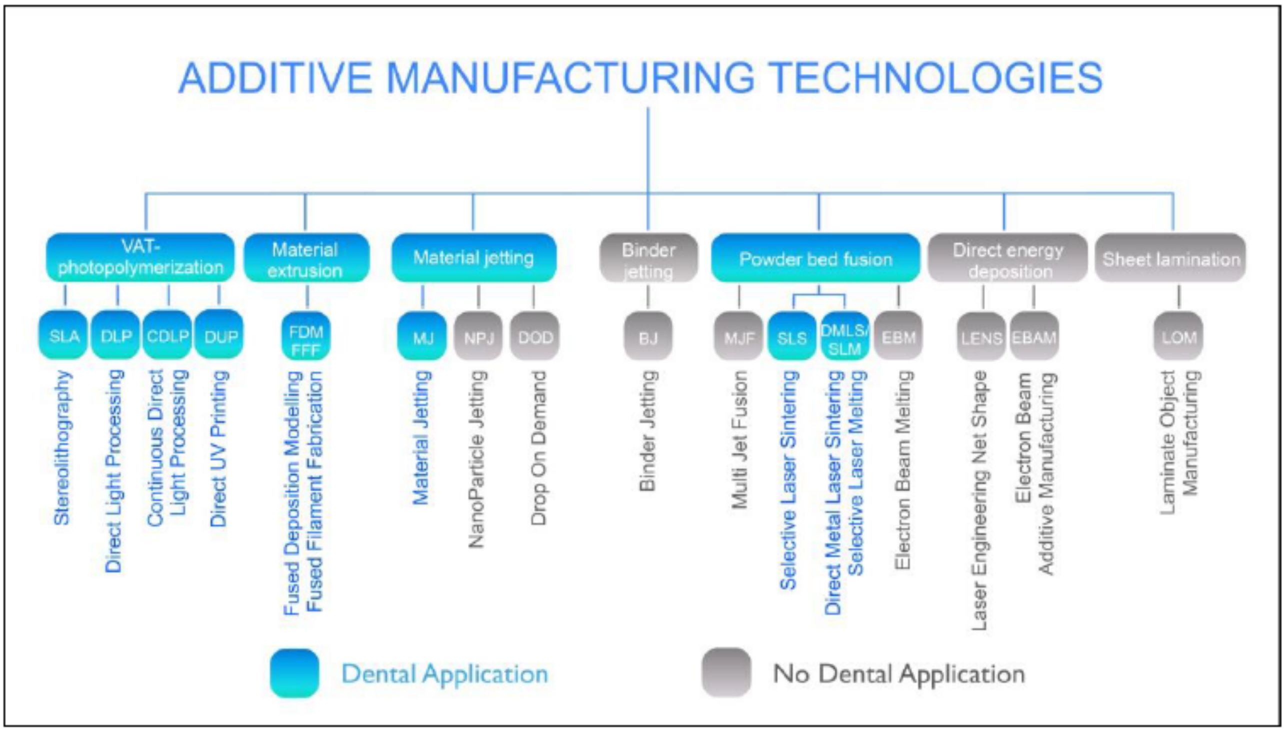

Figure 1

DENTAL INDICATIONS AND APPLICATIONS OF 3D PRINTING

Additive Manufacturing and Metals

Since 2002, the dental industry has effectively employed metal alloy additive manufacturing. At the time, the production of non-precious alloys underwent a revolution with the introduction of laser sintering into the dental profession [9].

For the fabrication of CoCr crowns and bridges, laser sintering is now the accepted procedure [10]. Laser-sintered non-precious metal crown and bridge frameworks have mechanical and physical characteristics that are similar to cast restorations [11].

In 1930, Dr. F. E. Roach wrote in the Journal of the American Dental Association [12]: "The clasp is the oldest and still is and probably will continue to be the most practical and popular means of anchoring partial dentures".

Clasp-retained dentures, sometimes called one-piece cast denture,a simple type of restoration that may be used anywhere and offer a lot of customization options [13] One-piece prosthesis can be digitally planned and produced additively using 3D printing or subtractively using CNC milling machines using computer-aided design/computer-aided manufacturing (CAD/CAM) and additive manufacturing technology [14]. This is where the differences between direct and indirect fabrication techniques may be seen. In the indirect process, lost-wax casting is used to create the frames, which are first printed in wax or plastic. The direct technique uses laser sintering to directly transform the CAD data set into a Co-Cr alloy product[15,16]

Advantages of laser sintering in digital manufacturing have been highlighted in recent articles [17], including easier digital data transfer, shorter production times, and uniformity.

Figure 2. Laser sintered CoCr Crowns and Bridges

Hybrid Manufacturing

In digital dental technology, a mix of additive and subtractive stages is referred to as hybrid production, with the goal of fusing the accuracy of CNC milling with the efficiency of additive manufacturing [18,19]. The characteristics of objects produced using hybrid procedures include enhanced surface structures, increased fit precision, and reduced costs

Additive Manufacturing and Polymers

For the additive production of plastic things, there are several 3D printing technologies available [20]. Nowadays, the dentistry industry mostly uses stereolithographic methods. These include the traditional laser-based stereolithography known as stereolithography (SLA) and the so-called mask exposure processes, also known as digital light processing (DLP). In both procedures, light acting in a photopolymer vat solidifies the product.

Low-cost liquid crystal (LCD) displays have been used in 3D printers for almost three years now. Direct ultraviolet printing, or DUP, is the technology that exposes the build platform pixel by pixel via LCD screens. For backdrop lighting, UV LEDs with a wavelength range of 395 to 405 nm is typically utilized.

Dental applications also make advantage of direct 3D printing techniques, such as material jetting, or MJT.Stratasys' multi-material 3D printing is a unique technology that merits note since it enables the simultaneous processing of many colors and materials with various qualities in a single build. Because they are limited to lower resolutions and need lengthy printing periods, material extrusion (MEX) methods like fused-filament fabrication (FFF) and fused deposition modeling (FDM) are currently less relevant in the dentistry market. From a technological and financial perspective, SLA, DLP, and MJT seem to be the most intriguing technologies discussed for the plastics industry [21–24].

Stereolithography Using a Laser Source (SLA)

The earliest 3D printing methods to hit the market were stereolithographic devices, which harden liquids using laser beams. As early as the 1980s, Charles Hull had submitted a patent application for the first stereolithography printer. The initial gadgets were quite costly and comprehensive. In contrast, the most recent generation of stereolithographic printers has become very affordable. For the past five years or more, Formlabs (Sommerville, MA, USA) has been providing 3D printers for dentistry purposes. Even though construction takes far longer than with DLP printers, this incredibly inexpensive device is a great way to get started with 3D printing technologies providing 3D printers for dentistry purposes. Even though construction takes far longer than with DLP printers, this incredibly inexpensive device is a great way to get started with 3D printing technologies.

Digital Light Processing (DLP)

In the dentistry industry today, digital light processing is likely one of the most widely used additive manufacturing techniques, along with stereolithography. The primary distinction between the designs of a DLP and SLA printer is the type of light source that is employed. A laser beam aids in the curing of the photopolymer in the SLA printer. Instead, DLP printers use Texas Instruments projection technology, in which a digital micromirror device (DMD), which is the fundamental component of DLP technology, guides short-wave light at the currently-used wavelengths of 380 nm and 405 nm. Square micromirrors with a regulated edge length of about 16 micrometres are used in the system.

The light is focused optically onto the build platform, which is contained within a clear photopolymer vat (photopolymer bath), or onto a diffuse surface (absorber). This is performed by tilting the unit's individual micromirrors, which are actuated by electrostatic field forces [25].

Material Jetting (MJT)

Similar to 2D printing, material jetting applies the material directly to the build platform via the print head. It then cures in an intermediary exposure stage, layer by layer constructing the product. The Polyjet method (Stratasys, Eden Prairie, MN, USA) is the most well-known example of this technology; it is distinguished by a very quick build time and great precision [26]. Multi-material 3D printing is a unique capability that allows for the printing of five distinct material grades in over 500,000 colors [27].

Useful Indications for AM of Polymers

- Model fabrication based on intraoral scan data
- Templates (drilling stents) for guided implant surgery
- Custom impression trays
- Production of occlusal splints
- Production of realistic training models
- Production of graphic 3d models

CONCLUSION

Additive technology will undoubtedly eventually replace several steps, if not the entire human denture-making process. Only the visualization phase of the CAD/CAM process will require specialized control and involvement. Throughout the construction process, additive techniques offer the important benefit of allowing for individual property control. Both mechanical and cosmetic qualities fall under this. In contrast, the created milling blank determines these properties in subtractive procedures. Complete denture additive manufacturing is currently the subject of an increasing number of publications. The outcomes show promise in terms of surface quality, fit, and mechanical strength.

A thorough analysis of biocompatibility is necessary since the denture bases have extensive area interaction with the oral mucosa. In particular, elution behavior and cytotoxicity must be investigated before final assessment is made [28]. 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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