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Digital Dentistry — 3D Printing Applications

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ABSTRACT

Three-dimensional (3D) printing is an additive manufacturing method in which a 3D item is formed by laying down successive layers of material. 3D printers are machines that produce representations of objects either planned with a CAD program or scanned with a 3D scanner. Printing is a method for replicating text and pictures, typically with ink on paper. We can print different dental pieces using different methods such as selective laser sintering (SLS), stereolithography, fused deposition modeling, and laminated object manufacturing. The materials are certified for printing individual impression trays, orthodontic models, gingiva mask, and different prosthetic objects. The material can reach a flexural strength of more than 80 MPa. 3D printing takes the effectiveness of digital projects to the production phase. Dental laboratories are able to produce crowns, bridges, stone models, and various orthodontic appliances by methods that combine oral scanning, 3D printing, and CAD/CAM design. Modern 3D printing has been used for the development of prototypes for several years, and it has begun to find its use in the world of manufacturing. Digital technology and 3D printing have significantly elevated the rate of success in dental implantology using custom surgical guides and improving the quality and accuracy of dental work.

Keywords: 3D printing, digital dentistry, dental materials, bone augmentation

INTRODUCTION

Over the past 30 years, 3D printing and prototyping has gained popularity within the profession and among patients alike. It has provided comfort and better quality of restoration to dentists. Moreover, dental restorations, which are being produced through rapid prototyping, are more adaptive and faster in production compared to the restorations created by dental technicians. This review article highlights the history and current technologies related to 3D printing.

HISTORY OF 3D PRINTING

3D printing has been used increasingly since the 1980s. In 1983, Charles Hull printed, for the first time, a three-dimensional object. He created the first 3D printer that used the technique of stereolithography, as well as the first program

for virtualization. They received increased attention in fields such as architecture due to the increased potential in the direct construction of parts, aeronautics because of the ease of making various small parts used in spacecraft construction, and technical subassemblies used in telecommunications domain. Their use in areas that require millimetric precision, has drawn the attention of specialists in general medicine, who started to implement it since the 1990s.[1]

3D modeling technologies and techniques are developing due to the increased popularity of 3D printers.[2] Among additive manufacturing techniques, dimensional printing is a relatively new technique that offers the possibility to produce a variety of geometrical pieces using various materials in the form of powder and binder.[3]

In prosthetic treatments, computerized scanning systems and 3D printing systems have come largely to replace traditional techniques for producing prosthetic works.[4,5] The applications used in the development of 3D printed parts use mostly technology for manufacturing various mechanical parts, and special computer programs that contain libraries of objects are needed to achieve design pieces.[6] Dental work patterns can be imported by scanning various prosthetic fields or using computerized imaging results (cone beam computed tomography). Dentistry is familiar with the CAD/CAM technique.[7] The new techniques of making prosthetic restorations largely eliminate the help given by dental laboratories.[8]

3D PRINTING TECHNOLOGIES USED IN DENTAL MEDICINE

3D printing technologies used in dentistry include, among others, selective laser melting, stereolithography, fuse deposition modeling, and digital light processing.

Selective laser melting

Making metallic frameworks by selective laser melting technology is one of the most promising directions for solving various problems encountered during casting alloys.[9] Selective laser melting is a technique of layer by layer addition that generates 3D pieces by strengthening selective and successive layers of powder material, one above the other, using heat generated by a computer-controlled laser radiation.[10]

Stereolithography

The most popular rapid prototyping technology is stereolithography, a device invented by Charles Hull in the 1980's. This device was the first commercially available printer for rapid prototyping. The principle is based on a photosensitive monomer resin, which forms a polymer and solidifies when exposed to ultraviolet (UV) light. The reaction created by UV light takes place only on the surface of the material.[11]

Fuse deposition modeling

The 3D printer uses a computer-aided model or scan information from which it extrudes and deposits melted thermoplastic polycarbonate, in a layered fashion, to build objects from bottom to top. The layers of melted plastic instantly combine with each other, thus making very complex parts that are easy to produce. The resulting aspect of the finished object can be used in combination with several materials such as acrylic or wax.[12]

Digital light processing

A projector light source is curing the liquid resin layer by layer. The object is constructed on an elevating platform. The layer is created upside down.[13] The polymer is layered pending the object is constructed, and the residual liquid polymer is drained off.[14]

USES OF 3D PRINTING IN DENTISTRY

Oral surgery

Anatomical models made using rapid prototyping methods are a novel approach to surgical planning and simulation. Such methods allow the replication of anatomical items, including three-dimensional physical models of the skull or other structures that allow the surgeon to obtain an overview of complex structures before surgery. The migration from a visual environment to one that allows both visual and touch interactions introduces a new code called "touch to comprehend".[15]

Chemical data indicate that rapid prototyping helps to minimize the risks that might occur during surgery. 3D printing techniques can be used in areas such as oral surgery — by making surgical guides and conducting various blocks to augment bone defects, and for learning modules — to create mandibles and jaws that can be easily showed to the students.[16]

Implantology

The utilization of tooth implants has rapidly evolved within the last 20 years. Studies in the field of oral implantol-

ogy led to predictable restorative options both for patients that are partially or totally edentulous. Positioning the implant in improper locations has the effect of decreasing predictability of the implant-supported prosthesis.[17] The use of 3D printing technology has gained popularity in dental implantology due to the introduction of guidelines of the surgical procedure to insert a dental implant.[18] Rapid prototyping techniques allow industrial or customized manufacturing of 3D objects by using data taken from a computer.[19]

3D printers can print bone tissue tailored to the requirements of the patient, and can act as biomimetic scaffolds for bone cell enhancement and tissular growth and differentiation.[20] In bone regeneration procedures, novel 3D printed alginate-peptide hybrid scaffolds can also be used. Studies indicate that the alginate-based scaffolds provide a stable environment for the growth of stem cells.[21]

We can create composite powders that can be printed into scaffolds. Calcium phosphate (CaP) powders can be mixed with a 3D printing (3DP) powder based on calcium sulphate ($CaSO_4$), and the scaffolds can also be used as bone augmentation material.[22]

Maxillofacial prosthesis

The absence of parts of the external ear can be caused by congenital disorders or can be acquired. When trying to restore these missing parts with prosthetic materials, the prosthesis should be customized for a better understanding of its part in the complex. When defects are unilateral, it is best to scan the opposite side and restore the affected side by duplication. Besides ears, scientists have managed to print cartilage and blood cells.[22,23]

Prosthodontics

Custom trays can be manufactured from computerized scans of impressions/models and printed, or can be created with readily available materials. There are two methods that are used for the development of study models for working in a virtual setting. The initial method includes scanning of the impression and transferring it into a program. The second method consists in taking the impression with a stock or semi-custom tray and pouring the model in stone. The stone prototype can be scanned or used directly in the manufacturing protocol. If needed, the study prototype can be replicated with duplicating hydrocolloid or printed, provided that a good quality scan is present. [11]

ADVANTAGES AND DISADVANTAGES OF 3D PRINTING

If we compare the advantages of 3D printed restorations with conventional or CAD/CAM restorations, 3D printing restorations will surely be placed on top. They provide the possibility of high quality restorations with quick and easy fabrication. The quality of these restorations has been demonstrated by several studies, although cost is still a major issue. The disadvantage of stereolithography and digital light processing is that they are available only with light-curable liquid polymers and the support materials must be removed. Also, resin is messy and can cause skin irritation, and it could also cause inflammation by contact and inhalation. Also, they present a limited shelf and vat life and cannot be heat-sterilized, while being a high-cost technology. The disadvantage of selective laser melting is that it is an extremely costly technology and a slow process.

CONCLUSION

By further research and technological advances, rapid prototyping will become a widely used method for 3D reconstructions in the dental laboratory. Nonetheless, even after all the technological developments in 3D printing, these methods cannot act as substitutes for the classical techniques that have been established in dental manufacturing. Correspondingly, the evidence presented in this manuscript calls for involvement to match the irreplaceable talent, skill, and knowledge of the dental technician.

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CONFLICT OF INTEREST

Nothing to declare.

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