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Modern facile dentistry: Boon to mankind

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Abstract
3D printing digital technology in the field of dentistry has revolutionized dentistry to its new vista. 3D printing in dentistry has its advantage to produce custom designs rapidly. Investing time in materials or storage space is out-gone. The dental laboratory can incorporate intraoral scan to in-house production with a seamless digital workflow. With minimal appointments 3D printing can produce more accurate, comfortable and effective dental appliances. 3D printing increase the success rate in treatment planning especially in dental implants because of custom made surgical guides. Digital scanners with CAD program ensure predictable outcome and precise appliance. Thus 3D printing have imminent capability in improving the oral health. It finds its applications in health care, research, treatment and education.

Keywords: 3D printing, custom design, digital technology, digital scanners, CAD program

Introduction
New era in medical and dental field has begun with 3D applications. 3D printing is a process of making physical objects from a 3 dimensional digital model. 3D printing is a preliminary version in additive manufacturing in which materials are joined and solidified using computer control. The shape or geometry of the object are designed using digital model data. 3D printing and 3D scanning has revolutionized dental treatment. 3D printing allows dentists to fabricate appliances and scaffolds that are not possible by other means. 3D printing enhance patient experience and practice. This technology fasten the task completion and permits customization (Fig: 1). 3D printing produce 3D solid objects from a digital data using 3D printer by joining, bonding, sintering and polymerizing small volume elements[18]. Thus 3D printing plays significant role in achieving personalized medicine care.

Fig 1: 3D Printing Machine

Techniques
3D printing also called additive manufacturing is a process of making 3 dimensional objects of any shape from a computerized digital image. The most common technology in 3D printing is Fused deposition modeling (FDM) invented and patented by S.Scott Crump in 1989 and was commercialized in 1990 by the company he cofounded, stratasys. The first step to make digital 3D model of any shape, is done by using a software called computer-aided design (CAD).

The 3D printer follow the instruction in the CAD file to initially build the foundation for the object by moving the print-head along the x-y plane and then build the object vertically by moving along the z axis, layer by layer allowing the fabrication of customized anatomical, medical and dental structures [26, 27]. The shape, color, texture and thickness of the object is obtained through the STL file format. The materials used are biocompatible. They are ABS petroleum based plastic (acrylonitrile butadiene styrene), stereolithography materials (epoxy resins), PLA, polyamide (nylon), glass-filled polyamide, silver, steel, titanium, photopolymers, wax, polycarbonate (PC) and high impact polystyrene (HIPS).

Types of 3D printing

Earlier 3D models are done by subtractive manufacturing, where a sharp tool is used to cut the material mechanically to achieve a desired geometric design with the help of computer program. This method reduce the manufacturing time but results in wastage. This drawbacks were overcome by the additive technology, wherein the materials are joined to make 3D objects usually layer by layer from 3D model data. The process of additive manufacturing of 3D models are fabricated using stereolithographic methods, fused deposition modelling, selective electron beam melting, laser powder forming and inkjet printing [26].

Applications

Applications of 3D printing in medicine and allied fields are quite diverse which includes bioprinting, tissues and organs, creation of customized prosthesis, implantable devices, pharmacological drug delivery [14, 18, 27], anatomic models for high risk surgeries and dental appliances. In dentistry 3D printing uses includes production of surgical guides for implants, production of physical models for prosthodontics, orthodontics and surgery, the manufacture of dental, craniomaxillofacial and orthopaedic implants, fabrication of copings and framework for dental and implant restoration. In additive manufacturing process the object is printed by adding the building material layer by layer. This method include fused deposition modelling (FDM), selective laser sintering (SLS), polyjet printing and bioprinting. Fused deposition modeling printers are used in medical and dental setup because of its wide availability, moderately reliable printing quality, ease of installation, and economic affordability. The commercially available highest resolution is polyjet printer [10]. It finds its uses in surgical planning on patient-specific 3D models, surgical stents and guides, phantoms for orthopedic and cardiac surgeries and scaffold for tissue engineering [8, 12, 21]. It also used in regenerative medicine, tissue engineering and research.

Oral and maxillofacial surgery

The additive manufacturing is used in oral and maxillofacial surgery, to fabricate the anatomical models using stereolithographic methods based on computerized tomography (CT) data [12]. These models have been beneficial for diagnosis, pre-surgical planning and act as a reference during surgery and in the manufacturing process of custom implant [6] (Fig:2). This has also led to the development of surgical drilling or cutting guides and more recently to individual bone grafts and scaffolds making 3D printing in oral and maxillofacial surgery an important tool.

The additive manufacturing can generate customized implants and scaffolds for bone and tissue regeneration by using biocompatible materials for orofacial defects. Regenerative materials like calcium phosphate, hydroxyapatite, β-tricalcium phosphate to polyglycolic acid and polylactic acid and magnesium-calcium silicate/ poly-ε-caprolactone, has been upgraded. 3D printing can tailor the scaffolds into desirable dimensions and can modify the properties of these materials with regards to porosity, surface texture and design [4, 5, 21, 28]. We can incorporate osteoinductive factors, like bone morphogenetic proteins (BMP-2 and BMP-7) for stimulating osteogenic potential [21, 24, 27]. We can fabricate of 3D printed titanium and zirconium implants. Considering the individual treatment plan, a simulated model of the final treatment outcome can be fabricated using 3D printing. This will help the patient to understand the surgical strategy and have a clear picture of the treatment outcome even before the surgery.

Fig 2: 3D Implant Model

Prosthodontics

Replacement of missing teeth has always been the basic requirement. With digital technology we can directly print the prosthesis from silicone, providing acceptable esthetics and reducing the number of appointments for the patient at the same time (Fig:3). Metallic and polymer-based materials are common in additive manufacturing of dental prosthesis and crowns. Most of the 3D printing techniques used are selective laser sintering, selective laser melting or stereography. But more research is required in accomplishing the state-of-art in ceramics manufactured by 3D printing. With 3D printing denture fabrication has become a more patient friendly procedure [9]. Fixed and removable dentures manufactured by 3D printing are clinically acceptable and have better physical properties comparable to conventionally fabricated dentures [6]. 3D printing can be successfully employed for metal implant prosthesis using selective laser melting and electron beam melting. Thus 3D technology can be employed to reduce the dreary work of a dental technician and provide error-free framework compared to the conventional framework. Metal crowns and interim resin restorations have shown comparable accuracy and marginal fit with respect to milled restorations [1]. The additive manufacturing has a positive role in prosthodontics, especially in patients with facial disabilities or gag reflexes. There is a shift in training dental students and professionals from typhodont to 3D printed models are based on intraoral scans.

Fig 3: 3D Restoration

Orthodontics

3D face scans and 3D printing print not only the anatomically correct and precise dental arches of patients but also orthodontic brackets [20]. We can achieve patient-specific adjustments in terms of angulation, bending, and material selection during the manufacture of brackets [15]. Within biomedicine the fundamental understanding of cartilage growth and bone biology is currently being tested in animal models to recast mandibular growth and modulate tooth movement. 3D printing in orthodontics is used for the production of orthodontic aligners for correcting misaligned teeth (Fig:4). These aligners can be removed at any time by the patient and in most cases they are only worn at night. These orthodontic aligners can be used on patients with slight malpositioning of the teeth or after fixed orthodontic treatment [23]. Using computer software, the teeth are digitally placed in the desired position. After presenting the 3D model, the patient-specific casting mold is created. The mold is printed using the stereolithography method where the product is built up layer by layer during the printing process. From the finished mold, the orthodontic aligner is then casted with silicone [19]. By digitally planning the tooth movement, designing the brackets tailored to the individual tooth surface and accurately positioning them using 3D-printed guides, it is possible to achieve the preferred treatment outcomes with expedition of the whole procedure. Furthermore, printing of guides for the placement of temporary anchorage devices or indirect bonding guides for the correct positioning of the brackets may play a major role in orthodontics in the future.

Fig 4: 3D Aligners

Endodontics

3D printing in endodontics has given rise to an unmatched streamlining of the procedure with greater precision and accuracy, ameliorating patient comfort, a breakthrough in regenerative endodontics and advancing the operator skills by training and education. Additive manufacturing has invaded the field of experimental regenerative endodontics by its capability to preserve the natural tooth. The principle of 3D printing deliver stem cells, pulp scaffolds, injectable calcium phosphates, growth factors and for gene therapy in the endodontics. Various types of calcium phosphate cements have been developed by 3D printing to form porous scaffolds for regeneration of the pulp-dentin complex [28]. 3D-printed polycaprolactone coated with freeze-dried platelet-rich plasma to the dental pulp cells has an improved osteogenic activity *in vitro* [16]. Anatomically shaped tooth-like tissue has been generated using 3D printed poly-epsilon-caprolactone and hydroxyapatite scaffolds [11]. Also, bioprinting approaches were developed using dentin-derived bionics. Additive manufacturing in endodontics finds application in guided apicoectomy and endodontic access cavity preparation.

Periodontics

3D printing in periodontology focus on periodontal regeneration and in esthetic gingival softtissue correction. The periodontium is a complex tissue system consisting of components like bone, gingiva and cementum. Each tissue has different properties and tissue regeneration in the oral cavity and controlled by different cell types, signaling mechanisms and interactions. By additive manufacturing, 3D-printed scaffolds to support tissue regeneration in a defect is used in periodontics [8]. However, damage to the periodontal tissue can also lead to difficulties in placing implant or cause failure in implant as the remaining tissue is not adequate in providing sufficient support for osseointegration. 3D printing finds its application in the procedure called guided tissue regeneration. The principle of controlled tissue regeneration is to prevent the ingrowth of rapidly regenerating tissues such as the oral epithelium into the defect and at the same time provide room to the slow-growing bone tissue for regeneration [3]. A CT scan of the defect in a patient serves as template for the creation of 3D objects. Based on the CT image, a printed wax mold is designed for the production of a scaffold that can be used to improve the immigration of periodontal ligament cells, which are responsible for the connection of dental cementum and tooth root. Improved regeneration of the alveolar tissue using 3D polycaprolactone (PCL) scaffolds has been proved. With the invention of 3D-printed biphasic scaffolds, it is now possible to utilize and guide multiple periodontal cell types during the healing process. Also scaffold-free approaches of bioprinting seem feasible as spheroids and more complex microtissues have been generated successfully from periodontal ligament and gingival cells. The application of such self-assembled building blocks for periodontal regeneration has been proposed. Clinically, 3D printing has gained popularity in gingival esthetic surgeries in the anterior region of the oral cavity [17]. Patient specific surgical guides are printed and used for gingivectomy procedures and smile designing. Such templates are known for their accuracy, customization, and precision.

Conclusion

Dental 3D printing is a modern dentistry. Digital dentistry customizes the objects and it is cost-effective and time-saving method. Preoperative computer simulation is an accurate method for designing and contouring. The 3D printed aligners are widely used. In maxillofacial and implant surgery 3D printing techniques assist in planning treatments for difficult cases. Implant may less invasive and more predictable with the use of surgical guides printed in resins. Although 3D printers are innovative, the cost of running, materials, maintenance and the need for skilled operators is necessary to consider along with the need for post-processing and following strict health and safety protocols. Despite these concerns it is clear that 3D printing will have an increasingly significant role in several industries such as automotives, aeronautics, games, research, medicine and dentistry. 3D dentistry will instill incredible change in the present world of dental care and will ensure facile dentistry in forthcoming years. However it needs to evolve for more scientific and regulatory challenges.

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