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RESEARCH ARTICLE

ROLE OF DIRECT 3D PRINTING IN MAXILLOFACIAL PROSTHESIS FABRICATION

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ABSTRACT

A maxillofacial prosthesis are successful treatment modality options such as to restore missing facial parts. Digital technologies and various 3D printing techniques are employed to construct facial prostheses such as ears, nose, eye. This is are view of literature enlightening the technique, materials and various applications of 3D printing that have been used in fabrication of maxillofacial prosthesis and in maxillofacial surgery.

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INTRODUCTION

Three-dimensional (3D) printing technology, was first demonstrated in 1986 they are also referred as additive manufacturing or rapid prototyping or solid free form technology [1]. This innovative technique has become significant over the time and had gained attention, within the head and neck surgical specialities; in maxillofacial prosthesis, otorhinolaryngology and plastic surgery, due to its remarkable capability to create complex structures with high precision and accuracy [2]. Direct or indirect molds are made for manual fabrication of definitive prostheses from conventional silicone because of limited availability of printed silicone materials[3,4]. Basic shapes of definitive prostheses are printed by direct manufacturing from an acrylate-based material coated with a colored silicone layer[5]. Starch powder based 3-dimensional (3D) printing system was developed by a company, which was subsequently vacuum-infiltrated with medical grade silicone [6]. Recent studies, the development of direct printable silicone has been reported[7]. Reconstruction, rehabilitation and regeneration have been the main areas benefited from these research projects using the 3D technology. Printing technology potentially offers reproducible, precise and durable patient-specific models for different surgical application; moreover, these were extended further to include teaching and education[8].

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Concept of Direct 3D Printing: Initially, scanning is done with scanning systems such as with a stationery 3D photogrammetry system to obtain an image of the entire face and measure its general proportions; and then a portable structured lights canner is used to provide the anatomy of the defect and any undercuts adjacent to the defect area.

Scans obtained from the scanners were matched, which will result in a 3D image of the entire face, including a highly defined defect anatomy. Computer-aided design (CAD) system is used to obtain a free form prosthesis without any standard templates. Initialdesign was obtained on the basis of photographs obtained from the patient. The scanned images will aid in proper orientation and formation of the prosthesis. The prosthesis edges were aligned to the virtual soft tissue adjacent to the defect. The prosthesis constructed was exported in standard tessellation language (STL) format and sent for direct printing. In direct printing crosslinker's Si-H groups react with the vinyl groups of the polymer to form a 3D network, hence this technology is based on platinum-catalyzed addition polymerization [9]. In direct printing technology in accordance with the STL mesh a single droplets are placed onto the working surface, ultraviolet (UV) light is used for the poymerization of each layer with thickness of 0.4 mm. The final prosthesis obtained after printing should be superficially finished with fine milling cutter such as to remove the staircase effect and to improve the color match.

Application of 3D printing in facial reconstructive: The surgical application of this technology is mainly focussed on four different aspects:

- To obtain highly accurate anatomic models to establish preoperative planning and improve postoperative facial contour symmetry, for example, reconstruction of any nasal, mandibular or maxillary defect. This will subsequently help to practice different techniques for better treatment outcome [10].
- Virtually planning and printing of pre-contoured anatomic structures to improve surgical outcomes and minimise operative time [11].
- Patients suffering from significant scarring, deformation and asymmetry can obtain accurate prostheses which will enhance the aesthetic and psychological status of the patient [11].
- Counterfeit models can be obtained to enhance surgical education at both undergraduate and postgraduate level [12].

Materials used in 3D Printing: Poly (glycolic acid) (PGA), polylactic acid (PLA) and copolymer (PLGA) are among many degradable polymers that have been investigated for maxillofacial defect repairs, were used broadly in the clinical environment [13]. Solid PLGA has osteoconductive properties in vivo, and subsequently the byproducts are removed by metabolic processes. Although, it has been found that, large PLGA prosthetics undergo bulk degradation on mechanical strain, that lead to rapid decrease in molecular weight and loss of strength thereby releasing high levels of glycolic acid and lactic acid resulting in pH level drop and tissue loss [14]. Another polymer that has been widely investigated and implementedis poly (ε-caprolactone) (PCL), which offers good biocompatibility and mechanical properties. This material has wide application in craniofacial reconstruction. It is found in a recent study that the combination of a 3D-printed polycaprolactone scaffold and dual spatiotemporal growth factor were delivered for regeneration of the temporomandibular joint articular disc[15].

Another case report has shown the potential of 3D-printed scaffolds for patient-specific applications in the craniofacial area[16]. In concept study, the potential use of 3D-printed bioceramic implants have been investigated for craniofacial reconstruction and these are printed from a bioceramic powder leading to formation of brushite resorbable implants. Electron beam melting was used to construct an anatomically precise mandible made of titanium. This 3D printed mandible was then implanted into a patient who had undergone severe mandibulectomy due to resection of a squamous cell carcinoma and on follow-up the mandible has demonstrated satisfactory aesthetics and implant stability outcomes with optimum osseointegration obtained with the titanium 3D-printed implants[17]. In various studies, the fit of these printed prosthesis was found to be clinically acceptable, which demonstrates the reliability and precision of the digital process. However, the marginal adaptation of some maxillofacial prosthesis was lacking in certain areas. The main reason for this drawback was the layer thickness which is slightly greater when compared to conventionally fabricated prosthesis. At the current stage of silicone printing technology, the prosthesis was only suitable as an interim postsurgical appliance. Even so, the prosthesis must be made from a medical grade (certified) silicone, which is not yet available for 3D printing.

Current limitations: The price of 3D technology is continuing to be driven down in terms of the price of devices, materials and software, despite the potential cost limitation [18]. For example, from an educational perspective, more 3D-printed educational models being available. The actual cost of 3D printed models should be compared to the cost of obtaining and storing their human tissue substitutes. The cost of the models obtained after 3D printing and software installation might vary depending on the material used. The accuracy of these models, however, is still a challenge to completely alternate human tissue [19]. More randomised clinical trials are required to prove the superiority of 3D printed models over the conventionally fabricated prosthesis, in terms of its surgical application. The articles available are more focussed on clinical case reports with only a few sample trial studies [20]. Another possible limitation is the time to produce a 3D-printed model. This includes scanning and capturing various scanned images to obtain anatomical scans, create a virtual 3D prototype, 3D printing is done from the desired material layer by layer followed by modification of the final structure. Although the limitations mentioned above are yet to overcome, with more modifications in materials and techniques such as to obtain desirable mechanical and biological properties. This indeed will reduce both the printing time and overall cost.

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