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A Review of Three Dimensional Process Flow in Surgical Treatment Planning

Research Article

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Abstract

Surgeons usually depend on their surgical training as well as medical imaging techniques such as magnetic resonance imaging (MRI) or computed tomography (CT) for the planning any surgical treatment process. Due to the anatomical complexity of the surgery site in head and neck region, 2D images are sometimes not sufficient to successfully analyze the structural details. In such cases a 3D printed model of the patient's anatomy enables customized preoperative planning. 3D printing technology is getting more and more attention especially in the craniofacial region. This article reviews the scope of this technology in maxillofacial surgery. 3D printing technology, also known as rapid prototyping or additive manufacturing or solid-freeform technology, was first demonstrated in the year 1986 [1]. Since then this technique has attracted significant attention, especially in maxillofacial surgery, due to the incredible ability to create complex constructs with highest possible precision. Reconstruction and rehabilitation using this technology offers precise and durable patient-specific models for various surgical applications.

Keywords: Rapid Prototyping; Additive Manufacturing; Surgical Planning; Preoperative Surgical Planning; 3D Printing.

Introduction

Surgeons usually face the challenging task of carrying out surgeries on complex anatomical structures in the head and neck region. Advances in medical imaging such as multi-detector computed tomography (MDCT) and magnetic resonance imaging (MRI) have made radiological diagnosis more informative and less invasive. MRI, CT and MDCT provide high resolution two-dimensional images, yet are constrained in their capacity to precisely delineate complex 3D structures.

3D reconstruction techniques offer a better understanding of structural complexity by allowing rotation and separation of layers in the 3D model.

Applications

Surgical applications of 3D technology can be listed as:

1. Acquiring accurate anatomic prototypes which ease preoperative planning and improve postoperative facial contour symmetry [2, 3].
2. Inspection of anatomy preoperatively, practice different surgical techniques and thereby reducing the operating time and minimizing errors [4, 19].
3. Virtually planning [5].
4. Printing pre-contoured grafts and plates to improve surgical outcomes [6].
5. 3D constructed prostheses [7, 8].
6. Cutting-edge simulation models to enhance surgical education [9].

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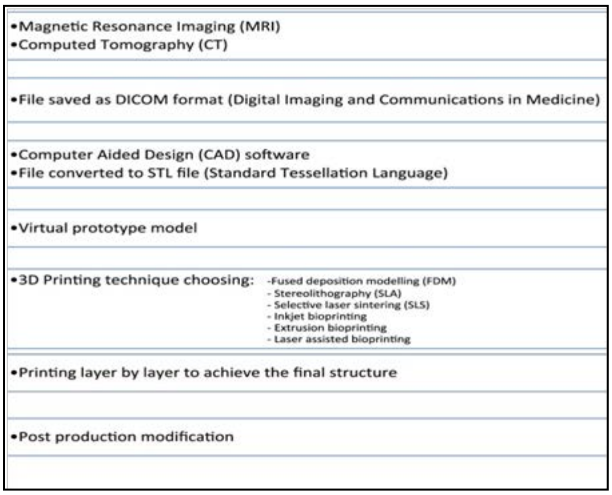
The concept of 3D printing can be summarized as [10, 11].



Workflow

The work flow behind 3D printing is summarized as [12, 14];

1. Capture anatomic structures using imaging techniques like magnetic resonance imaging (MRI) and computed tomography (CT)
2. Save the scan images in Digital Imaging and Communications in Medicine (DICOM) format
3. Use Computer-Aided Design (CAD) software to create a virtual 3D prototype
4. Use Standard Tessellation Language (STL) that allows for 3D printing
5. Select appropriate printing technique 20 like stereolithography (SLA), fused deposition modelling (FDM), selective laser sintering (SLS), bioprinting (laser-assisted, inkjet, extrusion)
6. Post-printing modification of the object to achieve final product.

Materials Used

Autogenous graft are considered as the gold standard for bone grafting as it has osteoinductive, osteoconductive and osteogenic properties [15]. Some disadvantages include donor-site morbidity, limited quantities, postoperative pain, resorption, wound infection, increased blood loss and prolonged anaesthesia time [16] as well as lack of delivering ideal geometry. Tissue engineering is hence a potential tool combining material science, engineering and biology to restore, replace or improve biological functions of the body.

Scores of biodegradable polymers have been investigated for maxillofacial defect repair including polyglycolic acid (PGA), polylactic acid (PLA) and copolymer of PGA and PLA (PLGA) [17]. This copolymer PLGA has osteoconductive properties *in vivo* and can be cleared by metabolic processes. When large PLGA prosthesis undergoes mechanical strain bulk degradation happens, releasing lactic acid and glycolic acid resulting in drop of pH and tissue loss [18]. Another polymer investigated for craniofacial reconstruction is poly (ε-caprolactone) (PCL), it has good biocompatibility and mechanical properties.

Other materials used are poly (propylene fumarate) (PPF) polymer, mesenchymal stem cells on a polyamide/hydroxyapatite scaffold, PEEK (poly ether ether ketone) etc.

Successful 3D printing from radiologic images is a multidisciplinary science. Accurate anatomical models require close interaction between radiologists and physicians. In terms of its surgical application, there is a need to design randomised clinical trials that prove the advantages of adopting 3D planning over the classical surgical treatment planning. A possible limitation to use is the time needed to produce a 3D-printed model [19].

Conclusion

In synopsis, the use of additive manufacturing technology in oral and maxillofacial surgery has good potential and can be utilized for careful surgical treatment planning. The generation of custom made implants might will address the downsides of current treatment strategies by creation of exact prototypes for fitting in the defect. Patient specific implants can thereby transform research, treatment methodology, and educational streams of dentistry ameliorating oral health care. 3D printing has a high potential for education in all disciplines of surgery.

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