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Review Article

Role of 3D Printing in Orthognathic Surgery

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Abstract

Technological advances in three-dimensional (3D) imaging, computer-assisted surgical planning and simulation in the field of medicine are now regularly being used for analysis of craniofacial structures. It also gained ingress in prediction of surgical outcomes in orthognathic surgery. A variety of patient-specific surgical guides and devices have been designed and manufactured using 3D printing technology, which rapidly gained widespread popularity to improve the outcomes. The article presents an overview of 3D printing technology and its applications in orthognathic surgery with emphasis on treatment feasibility and patient outcome.

Keywords: Orthognathic Surgery**,** craniofacial structures, 3D printing technology.

INTRODUCTION

3D printing is the process in which multiple layers of material are added one by one under computer control to create three-dimensional object. The main advantage of this innovation is that the three dimensional model is sliced into many thin layers and the manufacturing equipment uses this geometric data to build each layer sequentially until final desired product is completed [1-3].

The development of 3D printed models and patient-specific guides has improved surgical planning as well as the transfer of the surgical plan into the operating room for a better surgical result. Literature shows that numerous studies have reported and investigated the clinical experiences and effectiveness of 3D printing applications for orthognathic surgery [4, 5]. The clinical applications of 3D printers in orthognathic surgery include the production of occlusal splints, osteotomy/cutting guides, repositioning guides, spacers, fixation plates/implants and 3D printed models [6].

During surgery under 3D computerized planning, errors in landmark identification, planning process itself, and segment positioning during the fixation can undermine the precision of the surgery, since the intraoperative maxillary position greatly depends on the intermediate splint fabricated from the model surgery. Hence, this step is important for accurate maxillary positioning in conventional orthognathic surgery. Face-bow transfer, mounting of a dental cast onto the articulator, and the model surgery procedure are potential sources of random errors. Recent application of computer-assisted 3D virtual model surgery and 3D-printed intermediate occlusal splint is a useful method but not completely; nevertheless, it is not free from random error. Many studies have shown the advantages of virtual 3D surgical planning and application of computer-aided surgical procedure.

This comprehensive review throws light on the latest advances in the applications of 3D printing technology in orthognathic surgery, and provides insight pertaining to the implementation of the 3D printing for enhancing the treatment outcomes.

Occlusal Splints

Conventionally, the facbrication of an occlusal splint involves the use of plaster models, face-bow and articulator. The drawbacks of the conventional method are that it is time-consuming in addition to having non-controllable errors.[6] Compared to the conventional method, the digital-based occlusal splint provides high accuracy, reliability and consistency, as well as improved quantitative control and efficiency.

Schouman *et al*., proposed a cadaveric study to evaluate the accuracy of CAD/CAM generated maxillary cutting guides and intermediate splints in orthognathic surgery [7]. Zhou *et al*., also developed a CAD/CAM intermediate splint for maxillary positioning [8]. Ying *et al*., reported a prospective study to investigate the efficacy of combined guiding templates and splints fabricated by rapid prototyping technique for the correction of facial asymmetry associated with vertical maxillary excess and mandibular prognathism [9]. Shaheen *et al*., presented and validated a protocol for the design and 3D printing of final digital occlusal splints based on 3D virtual surgery planning. They reported that facial asymmetry was improved in all patients with satisfactory outcome, and the protocol had an acceptable clinical error margin; but also indicated that the technology could be future improved [10].

Osteotomy Guides and Repositioning Guides

Osteotomy guides are used to ensure that the osteotomy is placed exactly as in the digital planning, so that the repositioning guide can exactly place the bone segment in the desired position. Numerous studies have introduced the use of surgical guides for condylar position control and inferior alveolar nerve injury prevention during BSSO [11, 12]. They provided a reliable, innovative, and precise approach for translation of the virtual plan to the operating theater. The linear and angular differences between the virtual and postoperative image models were clinically acceptable. Numerous studies have evaluated the use of 3D printed repositioning guides as an alternative approach to intermediate surgical wafers for transferring virtual surgical plans into the intraoperative setting. They developed an easy-to-use CAD/CAM cutting guide and titanium fixation plate combination to facilitate the intraoperative reproduction of the surgical plan [13, 14]. Brunso *et al*., used bone-supported guides and computer designed titanium miniplates to provide position control with considerable surgical accuracy [15]. The novel method provided adequate vertical control and condyle positioning with surgical accuracy.

Spacers

In order to achieve facial symmetry and harmony, the spaces that occur following the LeFort I osteotomy for lengthening the vertical dimension of the maxilla and in BSSO after the rotation or shifting of the mandible in asymmetry cases and in genioplasty for vertical lengthening procedures should be maintained as planned during plate and screw fixation. Dumrongwongsiri et al. used different kinds of customized 3D-printed “spacers” to facilitate and stabilize the planned maxillary and mandibular segment position. These could fit easily in the desired position during the procedure and easily removed after rigid fixation of bone segments.[16]

Fixation plates/implants

Philippe et al. advocated the production of the titanium miniplates/guides utilizing a direct metal laser sintering technology [17]. Compared with the sintering technique, layer-by-layer construction is potentially less expensive and faster; on the other hand, it may result in lower rigidity and carries a higher risk of contamination. Huang *et al*., developed an optimal biomechanical miniplate using a 5-axes milling machine. When fixed onto the freed separate maxillary segments of a rapid prototyping model, the plates provided precise positioning/fixation and presented adequate strength/stability in the LeFort I osteotomy [18].

Advantages

Conventional standalone subtractive manufacturing techniques such as milling create high wastage by their very nature. This can be minimized by utilizing these techniques in adjunction with additive manufacturing. Among all the available digital processing methodologies used for this purpose, 3D printing clearly has an edge. Its higher efficiency, passivity, flexibility and superior material utilization earn it its distinction [9]. 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 [10].

Disadvantages

The benefits from high material utilization might in some cases diminish when compared to the drawbacks due to its extended postprocessing duration. Other shortcomings include its high cost, the occurrence of layered deposition, inconsistent reproduction and requirement of support materials. Ceramics, one of the most popular materials used in dentistry lacks the ability to be 3D printed due to the high porosity caused during fabrication [19].

The disadvantage of stereolithography and digital light processing is that they are available only with lightcurable 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 [20].

CONCLUSION

This extensive review discloses that various patient-specific 3D-printed surgical devices are progressively being used in orthognathic surgery. It can be concluded that this innovation is definetly beneficial to the clinicians as well as the patients. Superior kinds of materials with varying characteristics and capabilities of 3D printing technology are being explored. There are still many potential applications for future research and clinical application in orthognathic surgery.

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