



Integration Of 3d Printing and Virtual Surgical Planning in Orthognathic Surgery: A Contemporary Review

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ABSTRACT: *To improve the planning and outcome of orthognathic surgery 3D computed assisted technology can be used. 3D printing technology has gained a widespread popularity as a variety of patient specific surgical guides and devices has been designed using this method. 3D-printed models and surgical guides provide a more profound comprehension of complex craniofacial anatomy and spatial interactions than conventional techniques.*

KEYWORDS: 3D printing, computer assisted, orthognathic surgery, dentistry

I. INTRODUCTION

Orthognathic surgery (OGS) is typically used to address dentofacial abnormalities and achieve functional improvement in the dentoalveolar complex by repositioning the maxilla and mandible. Modern orthognathic surgery encompasses a wide range of surgical procedures, from straightforward single-jaw and double-jaw procedures to intricate cleft craniomaxillofacial orthognathic procedures[1]. Traditionally, radiography has been utilized for outcome evaluation, treatment planning, and assessment. The presentation and study of a complicated 3-dimensional (3D) maxillofacial structure in two dimensions is, however, limited by this method. Low-dose cone-beam computed tomography (CBCT) has been used extensively for evaluation and treatment planning in a variety of sectors because it enables the creation of a 3D skeletal model that precisely depicts the 3D shape and position of the craniofacial skeleton. The use of computer-aided design and manufacturing (CAD/CAM) techniques has been implemented to improve surgical procedure guiding and preoperative planning accuracy. In order to give precise guidance for preoperative planning and intraoperative execution for orthognathic surgery, 3D computer-assisted technology has been developed by integrating 3D image models and the CAD/CAM approach[2]. A thorough examination of the procedure shows that, although being a tried-and-true approach, the

use of dental splints in orthognathic surgery with traditional plaster study models is logically flawed and inaccurate in a number of ways. There is insufficient control over movements like rotation and translation in plaster model surgery when considering the entire cranial condition. After printing, the data from repositioning can be converted into a dental splint with the use of virtual blanks in the preoperative 3D modeling[3]. VSP significantly reduces the time required for surgical planning compared to traditional methods . It is time-saving and is not just beneficial for the surgical team but also minimizes the patient's preoperative stress and waiting time.

II. 3D PRINTING AND TREATMENT PLANNING OF ORTHOGNATHIC SURGERY

Preoperative planning is a thorough examination of medical pictures and other patient data in order to better understand the current issue and create a model that is appropriate for the patient. 3D-printed models have been used for preoperative planning in all surgical subspecialties. These models eliminate the requirement for intraoperative execution by accurately planning and simulating surgical operations, incisions, and the positioning and sizing of necessary hardware. It is also possible to create realistic and precise models that offer comprehensible visual aids[4].

Preoperative planning is the most important aspect of orthognathic surgery planning. Orthognathic surgical planning is limited by traditional 2D methods used for splint diagnosis, planning, and manufacture since they are unable to offer 3D information on anatomical components. Furthermore, low-resolution-related problems might lead to errors in the creation of a less-than-ideal plaster cast. The use of 3D printing in orthodontic operations, which offers high-resolution images to guarantee precise skeletodental models and splints when transferring anatomical landmarks, has addressed these drawbacks. Additionally, 3D printing guarantees minimal radiation exposure and a high degree of precision when capturing patient anatomy through high-resolution imaging. In a computerized workflow, this enhances jaw repositioning[5] .

Dental arches and skeletal architecture can now be modeled in 3D and digitized prior to planning thanks to the combined impact of these preoperative techniques. A high-resolution scan of the occlusal arches is essential to this procedure, which combines low-resolution and high-rate images from CT and CBCT[6]. Furthermore, a CT scan of skeletal anatomy, scanned plaster models, and a reference splint with fiducial markers enable a composite image of the dental-skeletal system. Both a double CBCT method and a triple CBCT process have been documented[7].

With its many uses, the innovative launch of a personalized 3D titanium implant stands out. These implants are known for their biocompatibility, which significantly reduces concerns like rejection or negative reactions, in addition to providing the crucial mechanical support needed for the challenged area. The treatment of orbital floor fractures is a noteworthy use of this technology, since it allows for the careful design of the implant, which takes inspiration from the anatomy of the opposing orbit to restore normal ocular movement. By combining the power of computer-aided design and manufacture (CAD/CAM) with electron beam melting technology, a customized titanium device has proven to be successful in the field of reconstructive efforts for deformities of the maxilla and mandible[8].

III. CUSTOMISED SURGICAL GUIDES AND IMPLANTS

The introduction of patient-specific 3D models aims to give precise and unique anatomical information for preoperative planning. These patient-specific technologies improve patient safety while cutting down on preoperative preparation and surgery time. These 3D-printed, anatomical models are customized to each patient and can be used for surgical planning both inside and outside of operating rooms[9]. By providing cross-sectional imaging or enabling the creation of prostheses tailored to the patient's anatomy, haptic models can be developed to aid in the planning of surgical techniques. It shortens the length of anesthesia and the number of implantation steps. When it comes to using 3D printing techniques for personalized prosthetics, orthopedic, maxillofacial, and cardiothoracic surgeries are regarded as trailblazers[10].

With the use of customized surgical guides, precise patient models are developed for the purpose of improving intraoperative guidance through the detailed visualization and simulation of surgical stages. The risks associated

with complex surgical procedures have been decreased as a result of these technical developments. The field of personalized implants and prostheses, which are essential for hastening patient recovery and guaranteeing the best possible rehabilitation results, has also been brought about by 3D printing, revolutionizing postoperative treatment. The advantages of these surgical models and guidelines that are 3D printed are multifaceted. First and foremost, they guarantee predictability throughout procedures by offering unmatched surgical precision catered to each patient's distinct anatomical characteristics. This level of accuracy, when paired with patient-specific instructions, can significantly reduce operating times and the likelihood of surgical problems.

The successful treatment of maxillofacial bone abnormalities has proven the effectiveness of the customized 3D implant. In order to improve the results of tooth rehabilitation, attempts have also been made to expand its use to include alveolar bone restoration. In these situations, the bone deficiency is repaired and tooth implantation is facilitated by using a specially made titanium tray enhanced with an iliac bone transplant. For individuals with hemifacial microsomia, hemi-mandible reconstruction is another notable use of the implant's unique architecture. The mandibular condyle, ramus, body, and tooth prosthesis are all essential parts of this design, which provides a complete and customized solution for these people's unique anatomical needs

IV. INTRAOPERATIVE NAVIGATION AND VERIFICATION

Surgical positioning guides and preoperative navigation planning were the two methods used to accomplish the intraoperative guidance, which was created in accordance with virtual planning. With CAD/CAM technology, two kinds of intraoperative positioning guides were created. To get the most accurate outcome of skeletal repositioning throughout the procedure, a real-time navigation system could be employed as an extra measurement and guide. Using the intraoperative navigation system should be preceded by preoperative navigation planning. For instant skeletal segment guidance and movement verification, intraoperative validation points were identified on a virtual surgical image. The main goals of the intraoperative examinations were harmony, face symmetry, aesthetic proportion, and sufficient tooth exposure. Furthermore, as indicated on the navigation screen, the intraoperative validation points that were obtained from the navigation plan were utilized to regulate the movement of bone segments by pointing to the mobilized bone and measuring the separation from the intended position. To make sure that the occlusal plane, upper tooth show, facial proportion, symmetry, skeletal midline, facial skin midline, and dental midline were all suitable, the facial appearance was checked several times [11].

To track the position of the patient and instruments in space, the intraoperative navigation systems included a computer digitizer. A reference star, or tracker, is affixed to the patient's skull while utilizing the real-time navigation system in order to indicate the patient's location within the system. In order to reflect the mathematical relationship that connects the patient's CT imaging space coordinates to their physical space coordinates, the patient is then registered to the navigation system using marker-based or surface matching registration methods. One possible issue with a real-time intraoperative navigation system is registration mistakes [12]. A guided precise registration technique could make the navigation system an effective tool for image- surgery. Because the original and new point are easily visible, the intraoperative validation points support both virtual planning and real-time bone position.

V. POSTOPERATIVE ASSESMENT

The purpose of postoperative evaluation is to gauge how accurately the treatment plan was transferred. Generally speaking, there are two ways to verify the translation of virtual planning: descriptive statistical analysis and color difference measurements [13]. A CBCT scan is performed after surgery. To assess the differences between the virtual surgical images and the postsurgical outcomes, a visual surface model superimposition was carried out following the initial registration of the simulated and real postsurgical images on the cranial base.

To examine if there is a statistically significant difference between certain cephalometric parameters of the virtual and real postoperative photographs, specific statistical analyses are selected for advanced quantification study of accuracy and reliability. All methods could be tested for intraexaminer and interexaminer reliability for the majority of the measures in the interim. Apart from assessing the dependability of virtual plan transfer,

postoperative evaluation was employed to appraise the accuracy of digital prediction, the treatment outcome, and the postoperative modifications in facial soft tissue and bone tissue.

VI. FUTURE DIRECTIONS AND LIMITATIONS

Eventhough 3D printing and VSP has an immense potential in these surgeries but have got their limitations. One of the main obstacles to implementing these technologies is the requirement for intensive software training. Experts must learn how to use the software used for developing and producing surgical guidance and 3D printed models. In addition to being time-consuming, this training could cost more money. Additionally, the program itself might have a challenging learning curve, particularly for individuals unfamiliar with CAD software.

Another factor that may prevent these technologies from being widely adopted is financial limitations. The price of purchasing and keeping up with the required hardware and software can add up. These cost factors can prevent certain healthcare organizations or individual practitioners from using these technology. The need on high-quality digital imagery for precise 3D printing and surgical planning is another drawback. Surgical guidance and printed models are only as accurate as the quality of the original digital scans. Digital models' accuracy may be impacted by patient-related factors including movement during imaging or dental prosthesis. The quality of the digital scans might also be affected by technical factors such artifact interference and image resolution. To guarantee an accurate depiction of the patient's anatomy, great care must be taken during the imaging procedure.

Furthermore, standards and regulations have not kept up with the quick growth and use of VSP and 3D printing. Consequently, there are issues with procedural accountability and patient safety. Establishing rules and regulations is essential to guaranteeing the caliber and dependability of these technologies. This includes software validation, standardized imaging methods, and quality-control procedures for surgery planning and 3D printing.

Future developments in technology should improve the accuracy, accessibility, and affordability of 3D printing and VSP in orthognathic and oral maxillofacial surgery. By automating some aspects of surgical planning, the integration of AI and machine learning could improve the usability and efficiency of these technologies. Furthermore, developments in biomaterials could result in the creation of 3D-printed implants that are tissue-engineered or bioresorbable, encouraging creativity in patient-specific care. Clear regulations and quality standards must be established in order to enable technology advancement and guarantee patient safety. These cutting-edge instruments are poised to usher in a new era of surgical care that is more precise and customized as research advances and technology develops[14].

VII. CONCLUSION

3D printing is at the forefront and has a significant impact on every aspect thanks to 3D imaging and CAD/CAM technology. Despite the fact that 3D printing is currently getting more affordable, issues with equipment maintenance, operating costs, and material usage remain. It is important to take into account the need for skilled operators, post-processing, and careful adherence to health and safety regulations. It is crucial that dentists stay up to date with technological advancements that could help both them and their patients in the future. Because of the dentist's natural curiosity and inventiveness, 3D printing is a promising technology that makes this a very exciting time to work in the field. Additionally, 3D printing makes it possible to evaluate surgical, preoperative, and postoperative treatments more quickly and accurately, which facilitates more effective and precise treatment planning.

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