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Editorial

Virtual Surgical Planning (VSP) : Ushering in a New Era For Craniomaxillofacial Reconstruction

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Craniomaxillofacial (CMF) injuries exhibit a range of patterns, from simple to complex. Performing craniomaxillofacial surgery is challenging and very demanding due to the complex anatomy of the facial region, having many vital organs and structures such as an intricate network of blood vessels and nerves, as well as the brain, eyes, nose and vital teeth. Surgeons typically invest considerable time and effort in devising the most effective surgical strategy to prevent harm to critical structures, which could otherwise result in functional impairments.

Since its introduction in the late 1980s, computer-assisted surgery (CAS) has evolved into a vital complement for craniofacial reconstruction. The advancement of virtual surgical planning (VSP) along with the accessibility of three-dimensional (3D) printing technologies has facilitated a more straightforward and reliable approach to the remodeling of the craniofacial skeleton. VSP tools are used to plan, design and manufacture surgical guides such as customized plates made of titanium, epoxide acrylate hydroxyapatite, hydroxyapatite or polyether ether ketone (PEEK). The custom-fitting surgical guide is created as a 'bridge' between virtual planning and surgery and eliminates the 'guesswork' intraoperatively. Recent developments in virtual surgical planning (VSP) have significantly improved reconstructive results in craniomaxillofacial aesthetic and reconstructive procedures. This technology proves particularly beneficial in cases characterized by spatial complexity, as it allows for the visualization and manipulation of three-dimensional configurations of the cranium through virtual surgery, the printing of stereolithographic (STL) models, the creation of cutting and positioning guides, the production of prefabricated hardware, and the enhancement of custom implants. VSP consists of several essential phases: data collection, CT image evaluation, 3D anthropometric assessment, surgical simulation, and the creation and manufacturing of patient-specific implants and surgical guides.

Instruments such as Romexis® CMF Surgery (Planmeca, Helsinki, Finland), ProPlan CMF® (Materialise, Leuven, Belgium), and Dolphin Imaging 3D Surgery® (Dolphin Imaging & Management Solutions, Los Angeles, CA, USA) enable thorough simulations of surgical procedures, encompassing skeletal structure osteotomies, post-oncological reconstruction, occlusion assessment, and soft tissue reactions to skeletal alterations. In numerous instances, VSP leads to greater accuracy, increased efficiency, and a reduction in operative time when compared to conventional methods. The VSP has been used for numerous types of orthognathic procedures including Le Fort I, II, III osteotomies, bilateral sagittal split osteotomies, distraction procedures of the upper and mid face, and genioplasties.

In the field of Orthognathic surgery, VSP offers more precise, predictable surgical planning and outcome. The initial phase involves an interactive online meeting between the surgeon and an engineer, during which they simulate the procedure, ensuring precise surgical placement of osteotomies and bone movements. The outcome is both an intermediate and a final splint that facilitates the clinical translation of the digital plan into the surgical environment. These splints are crafted with various customizable options, including the ability to minimize or maximize occlusal overlap, incorporate palatal strutting, create sandwich splints, and more.

Distractor positioning guides direct the position and orientation of the osteotomy and the location of the distractor footplates, thereby establishing the vector of distraction. The final surgical splints are manufactured from a transparent material that is approved for intraoral use for a duration of up to 30 days. Furthermore, additional surgical guides tailored to the patient can be produced as necessary.

In maxillofacial reconstruction, VSP reconstruction surgical guide is highly precise, Conservative one which enhances the prognosis of the surgical outcome. Resection guides are used to establish appropriate resection margins and, by extension, the precise interfaces between the resection margins and the reconstruction segment. Once these guides are created, the surgeon will ultimately choose specific cutting guides for the cancer surgery or resection. Due to the significant resection of tumors in many craniofacial cases that often involve the maxilla or mandible, the maxillofacial surgeon, neurosurgeon, and oncologist typically work together within an interdisciplinary management framework that emphasizes precise resection of the tumor or cancer margins. This necessity further highlights the requirement for vascularized bone grafts in the resected regions, as the bony defects or functional impairments created must be addressed by the surgeon. Vascularized bone grafts are the most frequently utilized grafts typically indicated for oncological cases involving most craniofacial tumors or cancers where bony reconstruction is necessary (for instance, the use of a fibula graft).

These surgical planning solution for distraction osteogenesis include designing placement of osteotomies, planning of distractor vectors and creation of templates for guidance of device placement, device bending and osteotomy placement. The patient's 3D anatomy is reviewed during the planning session, and underlying teeth roots and nerves are visualized for proper distractor placement. Each case is customized to the actual distractor file to be used during surgery. Some uses of VSP Distraction include osteotomy placement, identifying a distraction vector plan, creation of templates to guide device placement, and facilitation of pre-operative hardware set up.

VSP has also brought revolution in the field of maxillofacial trauma. This approach enables the surgeon to digitally align the fractured bone segments before the operation. The digitally adjusted plan is conveyed to the operating room via various models, guides, templates, or digital images. Given that these cases are often time-sensitive, 3D Systems prioritizes rapid service. The deliverables for VSP Trauma cases consist of patient-specific osteotomy and positioning guides, occlusal-based positioning splints, and digitally refined or mirrored anatomical models. The virtual substitution of the excised bone can be uncomplicated when the defect is minor and straightforward; however, in instances where the defect is extensive or intricate, it may be beneficial to overlay the normal contralateral side in a technique known as mirror imaging. Conversely, when the contralateral side is abnormal, generic data from a size-matched cohort can be utilized in a method referred to as cohort substitution. This approach is frequently advantageous in situations involving significant trauma or pronounced craniofacial deformities. A modified DICOM can be generated according to the surgical plan for application in intraoperative stereotactic navigation systems.

Jaw in a Day® facilitates the prompt insertion of a temporary dental prosthesis during a one-stage free tissue transfer jaw reconstruction procedure. The surgical planning, as well as the design of guides and prostheses, is executed utilizing advanced CAD/CAM technology, enabling the patient to leave the operating room after a single surgery with a complete jaw reconstruction, which encompasses dental rehabilitation.

Virtual Surgical Planning (VSP) has transformed intricate jaw surgeries by offering unmatched accuracy, decreasing surgical duration, and enhancing patient results. As technology continues to evolve, VSP is set to further reshape oral and maxillofacial surgery, rendering complex procedures safer, more reliable, and more attainable. One potential limitation of VSP CAD/CAM technology is its high cost, which leads to increased expenses for patients. However, as numerous studies have indicated, the qualitative benefits of VSP CAD/CAM can mitigate issues and reduce patient morbidity; therefore, these improved outcomes help to offset the elevated costs.