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Role of Virtual Surgical Planning in Pan Facial Trauma Reconstruction

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Abstract - With the aim of enhancing speed and accuracy for intricate surgical procedures, craniomaxillofacial surgeons have just begun using virtual surgical planning (VSP). Among its several uses, VSP has the potential to cure orbital fractures and other craniofacial abnormalities that might be either present at birth or developed over time. By illuminating the interplay between bone and neurovascular components, VSP helps the surgeon make sense of the craniofacial region's intricate anatomy. In this particular example, the patient suffered from pan facial trauma and had several facial bone fractures. In order to prepare for the operation, the surgeon used an AM medical model to customize the micro plates. In order to improve the results of complicated procedures, this article also discusses the significance of AM medical models.

Keywords: Virtual, surgical, craniomaxillofacial, complex.

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INTRODUCTION

Many obstacles exist in the surgical treatment of maxillofacial injuries. When planning surgical procedures, it is crucial to keep in mind that harming important structures might result in functional or sensory impairments. In order to prevent unsightly scarring, it is crucial to carefully position incisions. When fixing facial fractures, the surgeon has to make sure the face has the right breadth, height, and projection again so it looks good and works properly. Major advancements in as a supplement to the existing surgical approaches for treating craniofacial injuries, virtual surgical planning techniques and technology have been created. These approaches take into consideration constraints imposed by surgical access, soft tissue oedema, injury severity, and the need to maximize the utilisation of operating room (OR) resources.

Quoted as follows: "The man who is prepared has his battle half fought" written by Miguel Cervantes. The goal of creating and using virtual surgical planning software is to help surgeons be as well-prepared as possible for difficult bone repair and reconstruction procedures before they ever step foot in the operating room.

Virtual surgical planning, when done correctly, may allow the surgeon to make better and safer use of their time in the operating room. Reduced an aesthetic time and operating room/hospital expenses are the results of this. The average cost of operating room time at acute care hospitals in California ranges from $36 to $37 per minute, according to a recent survey of operating room costs. Operating room (OR) time may be better used and even reduced for complicated patients with careful preoperative planning and smart use of tools like intraoperative computed tomography (CT) and surgical navigation. Reducing the need for costly and sometimes dangerous revision surgeries, the ability to check appropriate bone connections intraoperatively utilizing surgical navigation or intraoperative CT further lowers healthcare costs and patient risk. We will go over the fundamentals and benefits of virtual surgical planning in a bit.

In order to begin using virtual surgical planning in any way, the first step is to acquire the necessary radiographic images in accordance with the established procedures. Prior to consulting with the hospital's face trauma specialists, a CT scan is often conducted. In an emergency trauma situation, a typical maxillofacial CT scan may help with injury diagnosis, but it might not be enough for virtual surgery planning. It is common for patients to need a repeat CT scan with thinner slices. Before sending data to a business that can aid in virtual surgical planning, be sure the imaging is acceptable. This will save valuable time.

Virtual surgical planning for trauma patients is quite similar to that for orthognathic surgery, for those who are acquainted with the technique. A corporate engineer who will be helping to fabricate the specialized devices or materials required for the procedure often engage in preoperative planning sessions with the surgeon electronically via web conferencing. After the patient's imaging data and, if needed, dental casts are submitted, a computerized three-dimensional (3D) model of their scanned anatomy is constructed. The surgeon may precisely arrange the osteotomies and bone reductions they want by manipulating the 3D DICOM information using virtual surgical planning software. Similar to traditional orthognathic surgery, custom cutting or reduction guides may be used in combination with occlusal splints to guide the intended osteotomies or reductions. The new or "final" DICOM information, which depicts the planned surgical procedures, is used to generate these instructions. It is possible to employ an intraoperative navigation (IN) software system to assess and guide reductions and osteotomies in real time during surgery by saving the final 3D locations of different bone segments as independent STL files. These files represent discrete anatomic segments.

LITERATURE AND REVIEW

Bou Zeid, (2024). Patients whose first panfacial fracture healing is inadequate may need late secondary reconstruction. Because of malunion and bone remodeling, it might be difficult to determine original face anatomy at this time. Surgeons may try to make patients' faces seem "ideal" by using their original CT image from after the incident to reduce fractures in a VR planning environment. Two patients who presented this operation was finished for a patient whose face was deformed because of a malunited pan facial fracture. Upon first CT scans after the injury and a cone-beam CT (CBCT) scan were performed on each patient. The pre-injury anatomy was recreated by virtual reality fracture reductions. In order to make surgical tools, the final model was superimposed with real-life anatomy. A 23-year-old male patient was the first to arrive with the diagnosis of midface bone malunion. Osteotomies of the naso-orbito-ethmoid (NOE) region, the left zygomaticomaxillary complex (ZMC), and the Lefort 1 segment all need specially constructed cutting guides. A 30-year-old female patient was the second one seen; she suffered from midface retrusion, malunion of the parasymphyseal fracture, and bilateral ZMC and sub condylar fractures. First, a Lefort I, and then, in the second step, It would involve performing a midline wedge excision in conjunction with a bilateral sagittal split osteotomy. In order to fix the issue of malar projection, a second procedure was scheduled to insert bespoke MEDPOR midface implants into the zygomatic and NOE areas. After successfully completing the surgery and meeting all aesthetic goals, both patients were released to go home.

Guo Y, (2018) Correcting midface and mandibular deficits are necessary components of facial skeletal restoration in cases when Treacher Collins syndrome (TCS) is quite severe. By using VSP, one may get a precise 3D picture of craniofacial anomalies, which helps with orthognathic surgery by allowing for bimaxillary motions, placement, and fixation, and with calvaria donors that are anatomically compatible with the intended malar augmentation. We detail the case of an 18-year-old TCS patient who had sliding genioplasty, a double-jaw osteotomy, and a phased zygomaticomaxillary reconstruction with the use of computer-assisted surgical planning. Not only did the patient's facial harmony improve after these procedures, but she also obtained class I occlusion.

Velarde, (2023). Diseases affecting the head and face, whether present at birth or developed over time, are the primary focus of craniomaxillofacial (CMF) surgery, a demanding and difficult area. The intricacy of the face and head necessitated the development and use of a wide range of surgical aids and methods to facilitate surgeries and achieve the best possible outcomes. The field of craniomaxillofacial the introduction of VSP has revolutionized the field of surgery. In order to plan and practice a surgical operation, it makes use of 3D imaging software. Research on VSP's use in craniomaxillofacial surgery is extensive. But this review was born out of the researchers' discovery of inconsistencies in the prior literature. By using an integrated method to synthesize the literature on VSP in craniomaxillofacial surgery, this work intends to provide a thorough assessment of the study results. A total of twenty-nine articles were carefully chosen for their relevance and then synthesized. The results showed that compared to the standard procedure, VSP delivers better duration, predictability, and clinical outcomes in craniomaxillofacial surgery. Most articles, meanwhile, failed to address the issue of cost. Consequently, this comprehensive literature review aims to provide the most recent information on VSP's use in craniomaxillofacial surgery, as well as any trends or suggestions for further study in this area.

Zoabi, A., Redenski, I., Oren, D., Kasem, A., Zigron, A., Daoud, S., Moskovich, L., Kablan, F., & Srouji, S. (2022). The capacity to swiftly produce intricate objects with exact geometry is what makes One notable difference between additive manufacturing and more traditional forms of production is 3D printing. Precision medicine is an essential tool for oral and maxillofacial surgeons, and this revolution has had an especially profound effect on their work. Several medical procedures have been enhanced by 3D technology, including orthognathic surgery, complete joint replacement therapy, and trauma therapies. With the advent of in-house infrastructure at point-of-care treatment centres made possible by the quick and broad adoption of 3D technologies in healthcare, surgical teams are now able to take part in the device's 3D design and production processes. Both the clinical results and the method by which doctors approach treatment planning have been profoundly affected by 3D technology. This study provides our thoughts on how 3D-based technologies might be used in maxillofacial and oral surgery, as well as some important clinical uses of these tools. In addition, the present research describes the idea of When it comes to 3D printing, treatment in the area of maxillofacial and oral surgery.

Sharaf, B. A., Morris, J. M., & Kuruoglu, D. (2021). Although 3D modelling and virtual surgical planning (VSP) have grown in importance in emergency craniomaxillofacial surgeries, it is essential to integrate these technologies at the point of care in order to treat patients with severe facial damage. This article provides a comprehensive overview of EPPOCRATIS, our method for managing acute craniomaxillofacial trauma. It also delves into what is now available, what challenges are there, and potential future paths for acute facial trauma treatment.

Case report :1

Presentation

A persistent infection in the left orbit, bleeding, discomfort in the eyes and sinuses, and other symptoms were reported by a female patient (Fig. 1). Six years before her presentation, the patient had suffered extensive panfacial fractures in a car accident, according to the patient. As shown in Figure 2a, the patient had face reconstruction done immediately after the accident; however, as shown in Figures 2b and c, the orbital plate had become misaligned and infected. During the examination, she had symptoms such as lower fornix purulent discharge, entropion, dystopia, and enophthalmos in her left eye. Scarring extended all the way to the implant under the retracted lower eyelid. The evaluation was followed by a planned procedure to remove the patient's left orbit hardware and rebuild their orbit with implants tailored to their unique needs.

Implant designed specifically for each patient

The surgical models and implant were digitally designed and created by DePuySynthes (Synthes® Maxillofacial 1302 Wrights Lane East, West Chester, PA) utilising data transferred to DICOM format from CT scans with 0.5 mm slice cuts (Fig. 3). The surgical team met virtually with a design engineer to go over the fabrication of the implant and the 3D model before production began. Prior to surgery, the implant and models underwent sterilization.

Combination, guidance during surgery

The removal of the contaminated hardware and the reconstructive phase were both aided by computerized navigation. Consistent navigational assistance during orbital floor management allowed the surgeon to better identify the precise location of anatomical structures using the patient's native anatomy, reducing the likelihood of injury to vital venous, arterial, and neurological systems (Fig. 4). To ensure the 3D implant was positioned and orientated as anticipated throughout underwent the procedure with the aid of intraoperative navigation. The 3D implant was inserted into the bone defect in line with the digitally indicated position after the last preoperative measurement was collected from the stereolithic model (Fig. 5). The predicted and actual locations were compared to validate the 3D implant site (Fig. 7). An operation to treat the was a lower eyelid flap progressed existing entropion and restore the lost lower eyelid tissue.

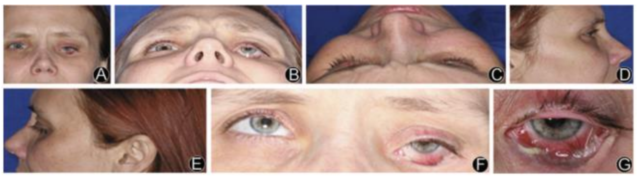

Figure 1. A: A portrait of the patient taken before surgery; B: a view from below, showing entropion; C: an overhead view of the patient; D: a view from the right side E: Opposite side view; G: Fluid discharge from the lower edge of the left eye's orbit; F: Limited upward eye movement.

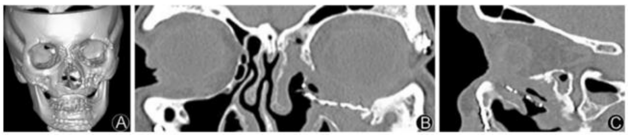

Figure 2. A: A history of extensive face reconstruction was found during the preoperative CT reconstruction. B: An axial CT scan of the orbital bone, with soft tissue displacement caused by infection, was shown. C: A sagittal CT scan of the skull showed that defective hardware was encroaching on the region of the maxillary sinus.

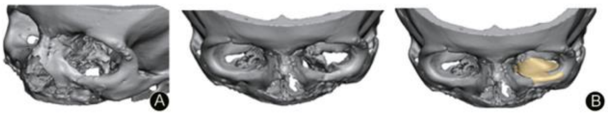

Figure 3. A: The orbital floor defect is shown in the rebuilt 3D model. B: The PSI is virtually positioned in the rebuilt 3D model.

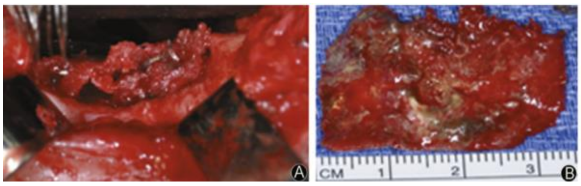

Figure 4. A metal plate that had been tissue-integrated was seen on the inferior orbital floor in the intraoperative imaging; B, defective hardware had been removed.

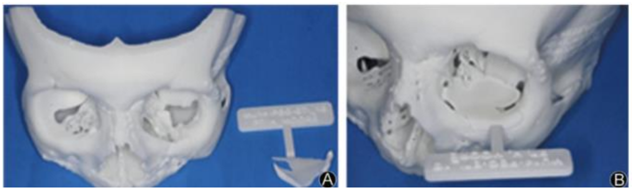

Figure 5. A: Intraoperative stereolithic model; B: Intraoperative stereolithic model modification.

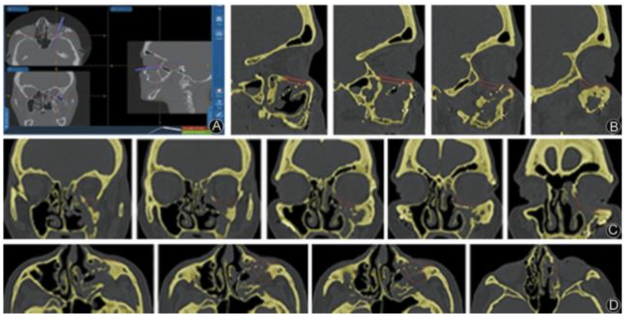

Figure 6. A screenshot of the intraoperative fusion navigation showing the probe indication; B: Three-dimensional (3D) implant placement in preoperative virtual surgical planning: the sagittal, coronal, and transversal sections; D: Three-dimensional (3D) implant placement in preoperative virtual surgical planning.

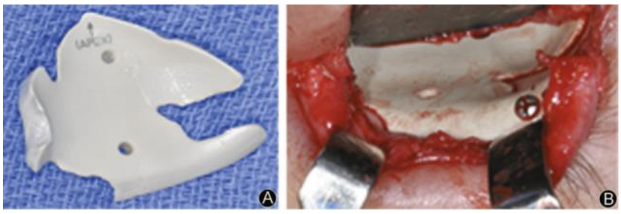

Figure 7. A three-dimensional model of the patient's implant taken from the stereolithographic data; B the surgical process of inserting the implant into the bone deficiency.

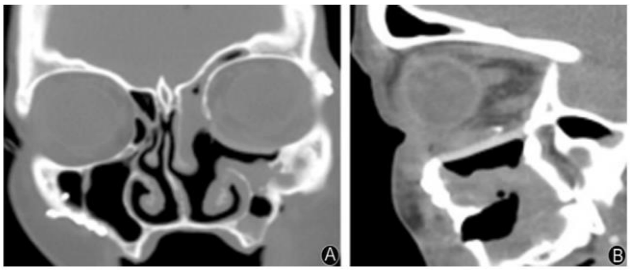

Figure 8. A: Coronal CT scan taken 5 weeks after surgery shows significant implant adaptation to the mesial wall; B: Sagittal CT scan taken 5 weeks after surgery shows significant implant adaptation to the posterior stop.

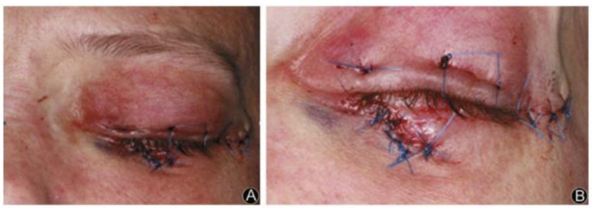

Figure 9. Here we can see two photos taken after the operation that clearly demonstrate the full closure of the patient's eyelids: (A) and (B).

Case Report :2

A male patient who was injured in a car accident is the subject of this case study. He was found to be bleeding from the nose and mouth as well as having several loose teeth in the front of his lower jaw. Conscious and able to understand and follow vocal instructions, the patient passed the clinical evaluation. It was a 15 out of 15 on the Glasgow coma scale. No clinical evidence of head trauma was found.

A variety of facial abnormalities were seen throughout the examination, including peri-orbital ecchymosis, nasal bridge flattening, subconjunctival haemorrhage, disordered occlusion, bleeding under the tongue, and missing front teeth (maxilla and mandibular). After evaluating the patient's symptoms, doctors tentatively diagnosed pan facial trauma and recommended a CT scan. 3D computed tomographic scans revealed a number of broken bones, including those in the fronto-nasal area, the maxillary sinus (on both sides), the mandibular Para symphysis (on the left side), and the dento-alveolar areas (on the front of the maxilla and mandible). This led to the final diagnosis of pan facial trauma for the patient. In the aftermath of a computed tomography (CT) scan, the DICOM pictures were processed using MIMICS software. Using this program, you may transform DICOM files into 3D CAD (Computer Aided Design) formats.

All of the patient's information, including what they're exposed to throughout the scan, is included in the CT scan. In the first step of the MIMICS program, the bony information is separated from the entire data using Hounsfield Units. Later on, you'll use tools like edit mask, cut, split, etc., to isolate the specific area of interest you need. The present instance involves injuries or fractures to the nasal, maxilla, and mandibular areas. Each fracture component is colour-coded differently for ease of identification and the severity of the fracture is easily detected after analyzing the fracture data from MIMICS. The STl file is prepared for the Fused Deposition Modelling method AM machine using the open-source CURA software. This program allows the user to alter the AM medical model's layer height, orientation, fill density, and operating temperature during construction. In this instance, a Maker Pi M14 machine is used to create a medical model.

An additive-based polylactic acid (PLA) filament is used. Fused deposition modelling (FDM) relies on the nozzle extruding filament at a controlled temperature and diameter to create a desired shape or model. The displacement of fractures and subsequent reductions informed the colour and component choices for the AM medical model. Achieved proper occlusion. Miniplates were bent to fit the anatomical structure's contours after the reduction was adequate. The medical model was meticulously planned in order to finalize the small plate's size and form. The patient had surgery while sedated and with nasotracheal intubation. The fractures were stabilized using the fronto-nasal region, the naso-maxillary buttress, and the zygomaticomaxillary buttress on the right and left sides, using plates and screws 2.0 mm in diameter, in line with standard surgical methods. The mandible was fastened using the appropriate screws and plates measuring 2.5 mm and 2.0 mm. The whole process lasted around two hours. The procedure took much less time and had precession. The plates had already been adjusted, so the reduction was straightforward and done correctly. Because of this, the operating time was reduced, and the risks associated with general anaesthesia were reduced as well. All was well with the patient's recovery. Radiographs performed after surgery confirmed the plates' positions and the bones' reductions.

Figure 10: X-ray of the individual.

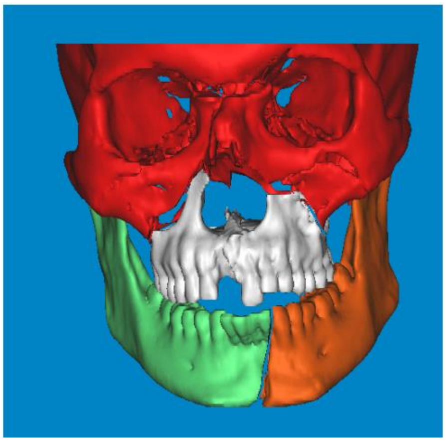

Figure 11: A patient's 3D CAD model.

Figure 12: A medical model for AM patients

Figure 13: After affixing tiny plates to patients, actual surgical images

Figure 14: An orthopantomogram was done after the operation.

Figure 15: Observing the nasal tubes and sinuses requires

RESULTS

When comparing the implant's placement to that of the unaffected side, postoperative CT revealed superb location (Fig. 8). The volume and boundaries of the maxillary and orbital sinuses have been restored (Fig. 9).

DISCUSSION

Fractures of the orbital bone are among the most prevalent complications of craniomaxillofacial injuries. A variety of facial fractures, both simple and more complicated ones involving the midface or upper face, may include the external orbit. Many vital tissues and neurovascular systems are located in the orbital region, making it an ideal target for trauma. There is less chance of iatrogenic harm now that surgeons can see the orbital architecture in real time because to advancements in computer imaging. Fractures of the orbital floor may be seen alone or in conjunction with other types of trauma, such as panfacial trauma. They are often described in conjunction with medial orbital wall fractures. Restoring and maintaining the initial orbital volume is the primary goal of orbital trauma therapy. After the left traumatized orbit was first treated, a hardware infection developed, necessitating a subsequent surgery in this case report. The many moving parts in removing hardware have made it a contentious issue in recent years.

Only patients experiencing symptoms and having given their correct permission should the reason to have implants removed after a fracture has healed be considered. It was clear that we needed a second operation due to the infection and the fact that the bone pieces had not fused. studied components of hardware removal in various patients. Out of 238 patients surveyed, only 20.2% had their hardware removed; among those who did, wound infection accounted for 20.8% of the total. Also, they found that there was a greater likelihood of removal for orbital rim plates compared to the bone plates of the jaw or face (p ¼ 0.02). Rates of elimination varied between 3.7% and 27.2% in other studies. The surgeon must take into account the possibility of hardware removal as a problem throughout the patient's healing process, even if it is rarely frequent. To lessen the likelihood of problems in those who have previously had an adverse event, it is necessary to execute subsequent surgeries with greater accuracy, better equipment dependability, and shorter surgical times. In such instances, VSP and patient-specific implants might be useful, enhancing the intraoperative phase and surgical planning process.

Section Fusion utilizes VSP for intraoperative guidance to determine the dimensions and positioning of the implant required to restore the orbital floor after a trauma. Large and uneven faults have also been included in previous research. Using the contralateral orbit as a reference, the precise orbital volume may be determined. The postoperative radiographic scan revealed that the implant was properly positioned throughout the space between the two sides of the orbit, and that the globe position had significantly improved, with the initial entropion completely resolved.

Plate bending during surgery may be a tedious process. By Using additive manufacturing to pre-bend, the plates of medical models shorten operating times. a reduction of around 40% in the amount of time needed to heal the mandible. Among the many benefits of using a computer to design and build a surgical procedure are: ideal positioning of the mandibular segments, time savings from not having to bend and adapt the plates multiple times during surgery, using the cortical bone's original surface as a guide to shape the recon plate, making preoperative surgical simulation easier, and restoring the patient's centric occlusion. The scientists concluded that the advantages of using AM medical models were similar. The adaptation accuracy of the small plates and the operating time were both significantly enhanced. Bony segment reduction to a satisfactory level and postoperative plating fracture were both helped by the pre-determined location.

CONCLUSION

In conclusion, both the pre- and post-operative phases of a surgical procedure may benefit from virtual surgical planning. While protecting the ocular neurovascular complex, VSP may enhance the accuracy and precision of implant and hardware placement. This example demonstrates how VSP and 3D patient-specific implants may provide surgeons with a viable therapeutic option for addressing complicated form problems without resorting to additional surgery.

It is unusual to see several fractures like this. Having to deal with several fractures makes the procedure more complex and time-consuming. The results are diminished when utilizing traditional CT or X-ray techniques to adjust tiny plates to the patient's anatomy, which becomes more challenging when fixing many places at once. Just as in this example, it's hard and time-consuming since there are several fractures and various moveable bone pieces. By customizing these small plates to the patient's almost normal anatomy using an AM medical model prior to surgery, we were able to reduce fracture fragments with precision and save a lot of time during the procedure. When compared to a total surgical time of 2 hours, the AM medical model cuts that time in half, or an hour. The authors imply that this method is useful and has additional potential applications. Frequently referred to as "3D printing," additive manufacturing involves a useful tool for the medical industry, according to the authors. Oral and maxillofacial surgeons are increasingly turning to 3D printing for a variety of procedures. In addition to reducing surgical time and complications, Diagnoses, patient education, and treatment planning are all made much easier with these models.

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