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Efficiency of virtual surgical planning in management of maxillofacial trauma

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Abstract

Background: Craniomaxillofacial (CMF) injuries has different patterns from simple to complicated ones. Surgeons usually spend time and effort planning the optimal surgical approach to avoid damage to vital structures that could otherwise lead to functional deficits. It is also imperative to optimize the skin incisions to avoid unfavourable scarring. The aim of this work is to assess the effectiveness and efficiency of virtual surgical planning (VSP) application in management of different types of CMF traumas, the advantages, and disadvantages of VSP, and the accuracy of three dimensional (3D) measures as a preoperative planning tool.

Methods: This prospective consecutive series study enrolled 30 patients presented with different types of CMF trauma. All patients were subjected to CT scans. The obtained Digital imaging and communications in Medicine (DICOM) files were imported into the software for virtual planning.

Results: The actual operative time (OT) after VSP was significantly lower than the expected time by traditional methods (p=0.008). There was no significant difference between the actual and expected number of incisions. The accuracy measures of preoperative VSP were very close postoperatively. The functional, anatomic reduction and patient satisfaction outcomes were very satisfying to the surgeon and the patient respectively.

Conclusions: VSP can be a valuable tool for optimizing functional and aesthetic outcomes of the CMF trauma surgery. The accurate measurements obtained pre-operatively helped in reducing surgical time and minimizing the need for subsequent revision surgeries.

Keywords: Virtual surgical planning, maxillofacial trauma, three- dimensional computed tomography, patient-specific implant, computer-assisted surgery

Introduction

Craniomaxillofacial (CMF) trauma surgery is a challenging field due to the unique anatomy and the wide variety of injuries in head and neck region [1]. Human history is facing a massive technological advancement in all fields of science and practice. Sometimes it is blamed for causing more insults and new injuries as those from road traffic accidents. On the other hand, it seems that technology is helping us again to heal some of these injuries in more efficient way. In late I980s the computer aided design (CAD) and virtual surgical planning (VSP) were introduced to the surgical practice using 3D imaging data from CT scans to assist in the surgical pathway [2].

The complexity of the different CMF trauma and availability of digital planning option had developed a need to use this technology in preoperative surgical planning to apply accurate restoration of the complex dimensions of the face. The application of VSP has an important value in different types of CMF surgeries including recent trauma, old ones, midface, orthognathic, zygomatico-maxillary complex (ZMC) and others related to tumors’ resection with cutting guides and reconstruction. This role was increased mostly after the developing of computer-aided manufacturing (CAM) technology such as 3D printing. This has created innovative options for fabricating new patient specific implant (PSI) to achieve better outcome [3]. The need for digital planning before surgery is increasing but there is a continuing concern about its accuracy [4]. The aim of this work was to assess: the effectiveness and efficiency of VSP in managing different types of maxillofacial trauma patients, the advantages and disadvantages of VSP and the accuracy of 3D diagnostics as a preoperative planning tool.

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Patients and Methods

This was a prospective consecutive case series study which was carried out on 30 patients aged from 19 to 51 years old, both sexes, who present with different types of CMF trauma to Otorhinolaryngology Department, Tanta University Hospital and Maxillofacial department in Nasser Institute hospital from June 2018 to April 2022. The study plan was approval from the Ethical Committee of Tanta University Hospitals. Patients included in the study were those who were fit for surgery with one of the following fresh / neglected CMF fractures: (ZMC fractures, Le Forte fractures, orbital walls fractures, frontal sinus fracture, mandibular fractures, and patients with facial contour abnormalities after old trauma or tumor resection).

Exclusion criteria were patients younger than 18 years, pregnancy, high risk of general anesthesia, uncontrolled diabetes, hypertension or active cardiac condition, COVID-19 positive swab test, severe bleeding tendency, coagulopathy disorders and Patients who refused surgery or participation in this study.

An informed written consent was obtained from all patients.

All patients were subjected to preoperative evaluation through clinical history taking, clinical examination (general, focal, and local examination). General examination was related to consciousness, responsiveness, neurological status, pulse, and blood pressure. Focal examination was done by complete head and neck with cranial nerves I–XII assessment while local examination was complete maxillofacial examination with more focus on the concerned area of lesion. Routine preoperative laboratory investigations were done.

All patients underwent CT scan bony and soft tissue windows on the head region with 0.5 mm pitch slice. The obtained DICOM files were imported into software either Mimics Medical 19.0 software or 3D Slicer. These medical images were processed through reorientation; segmentation of anatomical components and establishment of the 3D model that combines all data via registration or superimposition. The output 3D model showed the actual fracture or bony defect. Measures of the fractures were taken in 3 cardinal directions: X, Y and Z. The VSP software allowed manipulations of the 3D model to design the desired bony reductions and/or osteotomies precisely. The 3D model exhibited each fracture block separately, after which the angle of displacement and length of the fractured part were assessed. Virtual translations and rotations were then utilised to decrease the shattered portion to its anatomic location. Then, screws or plates were chosen for the fixing. Using the software's tools, the length, location, drilling position, and direction of the screws were calculated for screw fixation. In addition, the planned osteotomies were guided by bespoke cutting guides and occlusal splints that were created for intraoperative occlusion modification. Figure 1

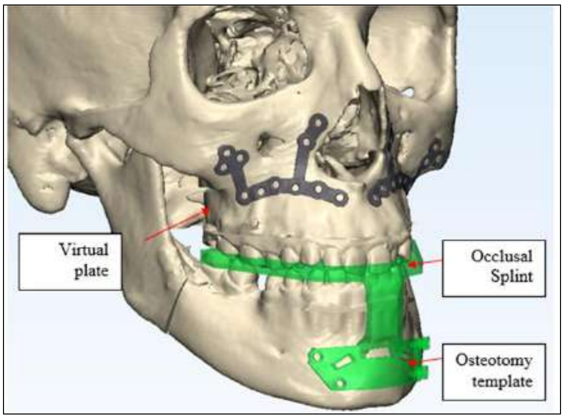

Fig 1: 3D virtually planned model showing the virtually planned plates “grey color” in an orthognathic case and occlusal splint with mandibular osteotomy cutting template.

The final 3D positions of various bony segments, guides or splints were saved as individual STL files that was printed later and manipulated individually intraoperatively to confirm osteotomies and reductions in favoured anatomical sites. For unilateral bony defects, If the lesion did not cross the midline, PSIs were designed based on a mirror image of the healthy half, taking into account the midline of the skull or mandible. Adjustments to the PSIs for abnormalities spanning the midline were based on a superimposed model of a patient with the same gender, age, and skeletal size. According to the PSIs' ultimate location, cutting guides are positioned were readjusted which were temporary fixed intraoperatively to the old bony structure during its cutting, contouring, and covering.

In patients with manipulations on mandible, orthognathic or mandibular reconstruction, planning of the occlusion was done before surgery. PSIs were customized to the individual patient’s anatomy. If the lesion did not cross the midline, PSIs were designed based on a mirror image of the healthy half, taking into account the midline of the skull or mandible. Adjustments to the PSIs for abnormalities spanning the midline were based on a superimposed model of a patient with the same gender, age, and skeletal size. According to the PSIs' ultimate location, cutting guides are positioned.

All the patients underwent general anaesthesia with nasal intubation or submental intubation and were operated by the same surgical team after planning the needed approaches and the expected operative time (OT).

Two weeks after surgery, a CT scan was performed. Imported DICOM data were transformed into various 3D models. Using the same software, the preoperatively designed 3D model and the actual postoperative 3D model were overlaid on each other in three planes relative to several fixed landmark sites on the skull. The sagittal plane was shown using cranial midline landmarks such as the Nasion, anterior nasal spine, posterior nasal spine, and glabella. The axial plane, which is the horizontal plane of Frankfort, was found using the unaffected side Porion point.

Through the unaffected side Porion point and perpendicular to both the sagittal and axial planes, the coronal plane was established. To quantify the difference, measurements of the distances between each point and the three planes of space were performed on both the preoperative VSP and the actual postoperative result. If a distance exists between two models in the postoperative CT model, the difference is computed in three planes: x, y, and z. By comparing both measures and angles, we were able to ascertain the VSP's degree of accuracy.

Outcome measures in our study were accuracy, OT, number of incisions, esthetic, anatomic, safe operation, and functional outcomes.

The accuracy outcome was measured by identifying the difference which was the average distance of deviation between preoperative planned 3D model and post-operative actual dimensions in relation to fixed skull points. The OT outcome was measured by comparing the actual OT of the surgeries with the expected OT.

The number of incisions outcome was also measured by comparing the expected number of incisions with the number of actual number of incisions were done in every case.

The esthetic outcome was measured both subjectively and objectively. Subjectively, the overall patient satisfaction with esthetic outcome was assessed after 3 months of surgery using a 5-point verbal scale ranging from very satisfied to very dissatisfied (1 for (very dissatisfied); 2 for (some-what dissatisfied); 3, for (neither satisfied nor dissatisfied); 4 for (some-what satisfied); 5 for (very satisfied [5] . Objectively, postoperative examination of all patients was done to detect symmetry and absence of scars from the performed incisions.

The anatomical outcome was measured by assessing the degree of the reduction and bone healing by radiological analysis postoperatively. The fracture reduction results were classified into perfect anatomic, basic anatomic and non-anatomic reduction. A perfect anatomic was one in which the fracture edges were anatomically aligned along contours without gaps or irregularities. A basic anatomic reduction was one in which there may have been a gap (<2 mm) between the fragments. A non-anatomic reduction was one in which there was a large gap between the concerned edges affecting the facial contours [6].

Safe operation outcome was assessed through recording the postoperative complications like scar alopecia, ectropion, temporary infraorbital hyposthesia, temporary unilateral or bilateral marginal mandibular hyposthesia, temporary unilateral or bilateral temporal branch of facial hypothesia, seroma, and limited wound dehiscence were recorded.

Functional outcome was assessed by clinical examination nerves and the concerned function according to the type of fracture. In patients with orbital trauma and NOE, vision, ocular muscles' motility in all cardinal directions and infraorbital nerve status were examined. In patients with mandibular intervention, mouth opening, and normal occlusion were assessed. In cases of frontal sinus fractures; frontal region irregularity and integrity of the supratrochlear and supraorbital nerves' function. Also, the patients were checked for the presence of any osteomylitic changes changing the facial contour.

Statistical analysis

SPSS v26 was used to do statistical analysis (IBM Inc., Chicago, IL, USA). Using the Shapiro-Wilks test and histograms, the normality of the data distribution was determined. Parametric quantitative data were given as mean and standard deviation (SD) and analysed using an unpaired student t-test. Non-parametric quantitative data were provided as the median and interquartile range (IQR) and analysed using the Mann Whitney test. A two-tailed P value of less than or equal to 0.05 was considered statistically significant.

Results:

The age of the study participants ranged from 19 to 51 years with a mean age of 32.3±8.82 years. Twenty-two (73%) of the study participants were male and eight (27%) were females. Regarding the chronicity of the lesion in the included cases; it was recent road traffic accident (RTA) in eighteen (60.0%) participants, old fracture in ten (33.33%) participants, and tumors in two (6.67%) participants. Regarding the type of included cases in the study participants, the most common type of trauma was orbital wall in 17 (57%) participants ZMC in 12 (40.0%) followed by frontal sinus fracture in 9 (30%) participants and 7 (23.33%) participants in mandibular fracture respectively. The least types of traumas were LE forte II in 3 (10.0%), LE forte III, LE forte I, NOE, tumors, and Orthognathic maxilla and mandible (MM) each occurring in 2 (7%) participants. (Table 1)

Table 1: Demographics, chronicity of the lesion of the study participants and type of included cases**.**

Study participants (n =30)		
Age (years)		32.3±8.82
Gender	Male	22 (73%)
	Female	8 (27%)
Chronicity of the lesion	Recent RTA	18 (60.0%)
	Old fracture	10 (33.33%)
	Tumors	2 (6.67%)
Type of included cases $^{\Delta}$	Orbital wall	17 (56.67%)
	ZMC	12 (40.0)
	Frontal sinus fracture	9 (30.0%)
	LE forte 3	2 (6.67%)
	LE forte 2	3 (10.0%)
	Mandibular fracture	7 (23.33%)
	LE forte 1	2 (6.67%)
	NOE	2 (6.67%)
	Tumors	2 (6.67%)
	Orthognathic MM	2 (6.67%)

Data are presented as mean±SD or frequency (%). RTA: Road traffic accident, Δ Each participant could have more than one type of trauma, ZMC: Zygomaticomaxillary Complex, NOE: Naso-orbito-ethmoid, Orthognathic MM: Orthognathic Maxilla and Mandible.

The actual OT after VSP using CAD was significantly lower than the expected time by traditional methods (p =0.008). There was no significant difference between the actual number of incisions used after VSP using CAD and computer aided manufacturing and the expected number of incisions that is used in the traditional methods. (Table 2).

Table 2: Operative time and number of incisions in the study participants.

	Expected	**Actual**	**p value**
Operative time (Minutes)	263.67±111.27	192.67±86.15	0.008*
Number of incisions	3.5 (2 - 5)	5 (2 - 5)	0.813

Data are presented as mean±SD or median (IQR), *Statistically significant as p ≤0.05.

Regarding the accuracy measure outcome, the 3D mean difference between the planned model and postoperative radiological results was 0.105±0.198 mm. (Table 3)

The overall patient satisfaction degree was very satisfied in 25 participants (83.33 %), satisfied in 3 participants (10 %), neither satisfied nor dissatisfied in 2 participants (6.67 %) and no one was dissatisfied or very dissatisfied. Regarding anatomic outcome, 26 patients had perfect anatomic reduction (86.67%), 4 patients had basic anatomic reduction (13.33%) and no one had non-anatomic reduction. (Table 3)

Regarding anatomic outcome, 26 patients had perfect anatomic reduction (86.67%), 4 patients had basic anatomic reduction (13.33%) and no one had non anatomic reduction. (Table 3)

Regarding complication, scar alopecia occurred in 1 (3.3%), ectropion occurred in 1(3.3%), temporary infraorbital hyposthesia 2 (6.7%), temporary unilateral temporal branch of facial hypothesia occurred in 1(3.3%), seroma occurred in 1 (3.3%), and limited wound dehiscence occurred in 1(3.3%). Wound infection, plate extrusion, PSI reaction or rejection, Malunion, and delayed post-operative malocclusion did not occur. (Table 3).

Table 3: Difference outcome between virtual model and post-operative radiological finding, patient satisfaction in the study participants, anatomic outcome, reduction degree and recorded complication rate results.

Study participants (n =30)		
Difference in implant displacement in x, y and z Directions (mm)		0.092 (-0.01 – 0.19)
Patient satisfaction	Very dissatisfied	0 (0.0%)
	Dissatisfied	0 (0.0%)
	Neither satisfied nor dissatisfied	2 (6.67%)
	Satisfied	3 (10.0%)
	Very satisfied	25 (83.33%)
Anatomic outcome and reduction degree	Perfect anatomic	26 (86.67%)
	Basic anatomic	4 (13.33%)
	Non-anatomic	0 (0.0%)
Recorded complication rate	Scar alopecia	1 (3.3%)
	Ectropion	1(3.3%)
	Temporary infraorbital hyposthesia	2 (6.7%)
	Temporary unilateral marginal mandibular hypothesia	1(3.3%)
	Temporary unilateral temporal branch of facial hypothesia	1(3.3%)
	Seroma	1(3.3%)
	Wound infection	0 (0.0%)
	Limited wound dehiscence	1(3.3%)
	Plate extrusion	0 (0.0%)
	PSI reaction or rejection	0 (0.0%)
	Malunion	0 (0.0%)
	Delayed post-operative malocclusion	0 (0.0%)

Data are presented as frequency (%) or Median (IQR).

Regarding functional outcome, all the nineteen operated orbital wall fracture or reconstruction had an intact motility in all cardinal direction and an intact infraorbital sensation. All ten cases with mandibular intervention had a full range of mouth opening and normal occlusion. All patients with frontal sinus trauma or bone loss had regular contour and no affection of the supratrochlear or supraorbital nerves. Only one patient from nineteen patients, operated for ZMC and Le Forte, had irregular contour at the infraorbital region. (Table 4).

Table 4: Functional outcome results.

Study participants (n =30)			
Orbital wall fracture and NOE (n=19)	Ocular muscles' movement	Intact in all cardinal directions	19 (100%)
	Infraorbital nerve function	Intact	
Mandibular intervention (n=10)	Mouth opening	Full range	10 (100%)
	Occlusion	Normal occlusion	
Frontal sinus deformity (n=9)	Frontal bone contour	Regular contour	9 (100%)
	Supratrochlear and supraorbital nerves function	Intact	9 (100%)
	Temporal branch of facial nerve	Intact	9 (100%)

Data are presented frequency (%)

Case presentations

1- Neglected ZMC with zygoma PSI

A 36-year-old man presented by old unrepaired ZMC fracture with bone loss and osteoporosis at the left inferior orbital margin. The patient was complaining from facial asymmetry at the infraorbital region. Preoperative clinical assessment and photographing was done with sample photos in (Figure 2 a). Preoperative radiological data was rendered and reformatted to 3D model like in (Figure 2 b). Then virtual planning for PSI was done with exact measurements which will adapt the patient. Figure 2 c. The next step was to send the PSI design for 3D printing laboratory using PEEK. Intraoperative plan was introducing the implant through left extended sublabial and subcilliary incisions plus left eyebrow incision to complete the fixation of the PSI to lateral orbital ridge like in (Figure 2 d). There was no major change in the intraoperative plan; the number of incisions was the same as planned, the PSI was exactly fixed with minimal reduction by drilling with a fissure burr. The postoperative result was near identical to the planned implant which is obvious in the postoperative 3D radiological model and real photos in (Figure 2 e and f).

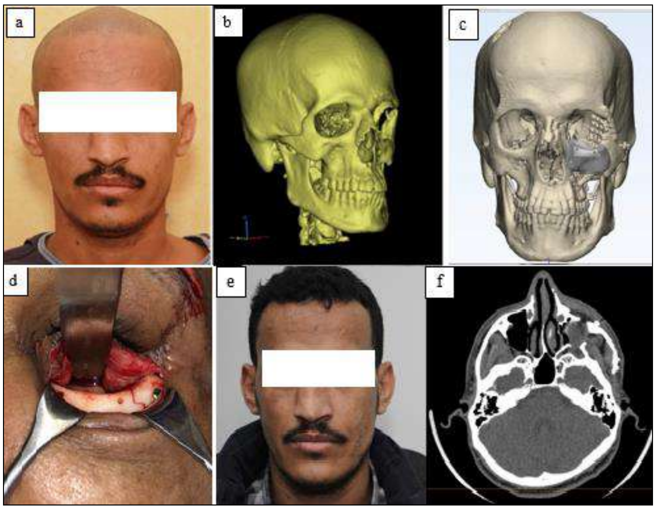

Fig 2: (a) Frontal view showing left sided infraorbital depression. (b) preoperative 3D reconstructed image showing the depression in left infraorbital region. (c) Preoperative 3D planning for the used implant with its relations to the adjacent structure in frontal view. (d) Intraoperative photos of the PSI through subciliary incision. (e) frontal view showing near identical infraorbital margins. (f) axial CT cut showing the PSI in place.

2. Orbital wall reconstruction

A 32-year-old woman was referred with a right orbital floor and medial wall blowout fracture after localized trauma. On examination, she had right sided enophthalmos with conjunctival hemorrhage (Figure 3a). Coronal CT scan data was showing extension of the orbital contents near the nasal septum (Figure 3b). The 3D DICOM data were then edited to digitally recreate the right orbital floor and medial orbital wall by matching the left side in order to reproduce its most likely form prior to damage. These final position DICOM data were then utilised to create a stereolithic model of the patient's skull (Figure 3 c). A commercial readymade 3D orbital floor and medial wall mesh implant (made of porous polyethylene on titanium mesh) was sized, trimmed, and bent before to surgery to perfectly match the geometry of the right orbital floor and medial wall on the stereolithic model. The plate and the stereolithic model were subsequently sanitised for surgical use. The orbital floor fracture was exposed intraoperatively by a transconjunctival incision with transcaruncular extension, and the remaining unbroken bone walls were discovered (Figure 3d). The mesh was then attached with two 4-mm screws once it was determined that the plate adapted well to the orbit's remaining bony walls and ledges. Postoperative photos showed reversed right enophthalmos in basal view of the patient after one week of surgery and she had a normal look after one month of surgery (Figure 3 e &f).

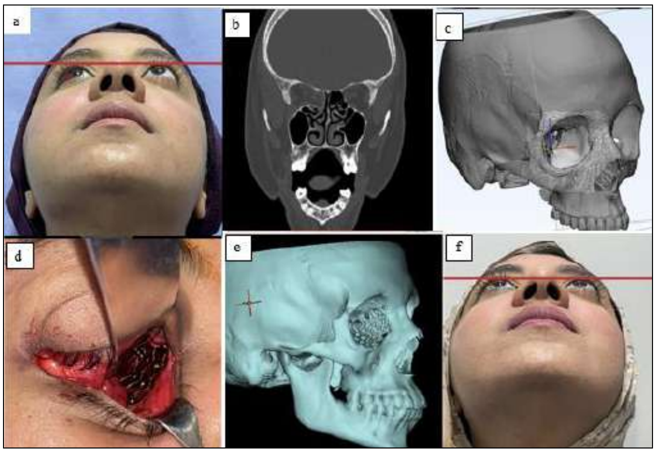

Fig 3: (a) Basal view of the patient showing right sided enophthalmos and conjunctival hemorrhage. (b) Coronal CT cut showing extension of the orbital contents near the nasal septum. (c) The planning model with dimensions in x, y and z axis which was used in adapting the mesh. (d)Intraoperative looks after adapting the titanium mesh to cover medial orbital wall. (e) 3D model showing restored medial orbital wall. (f) Normal look of the patient after one month of surgery.

2. Delayed reconstruction of ZMC

A 26-year-old male patient was involved in an automobile 5 years before being referral. The patient was dissatisfied with his appearance after the initial surgery performed after accident. Clinical examination revealed increased transverse dimension of his right zygoma.He had severely widened and underprojected left zygomatic prominence, with significant asymmetry of his mid face. (Figure 4 a) Radiological preoperative CT scan data were imported to show the preoperative 3D look of the considered bony parts. There was resorbed right zygoma with deficient lateral part of the right inferior orbital margin and anterior part of the orbital floor. (Figure 4 b) VSP was conducted to design the cutting guide and proper PSI which will cover all mentioned lost areas of support. The final 3D dataset was saved with bony segments represented in different colors that could be virtually manipulated, removed, added, and overlapped. (Figure 4 c) Intraoperative fixation of the implant was done by extended bicoronal incision. (Figure 4 d) The postoperative result was near identical to the planned implant which is obvious in the postoperative 3D radiological model and real photos showing regained facial contours and zygomatic eminence. Also, postoperative CT cuts were conclusive for the actual site of the implant. (Figure 4 e and f)

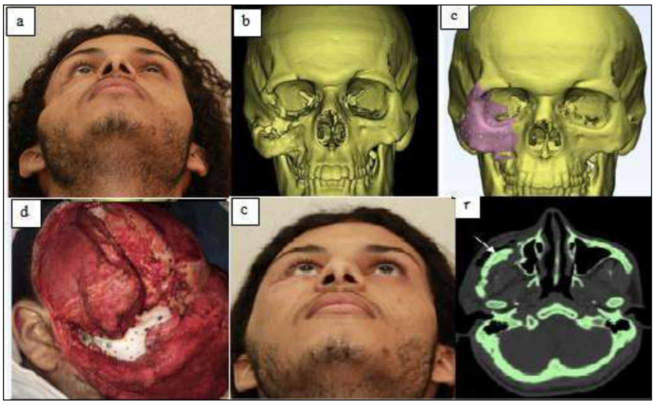

Fig 4: (a) Basal view of the patient showing the severe asymmetry in right side. (b) 3D radiological model showing deficient zygomatic bone. (c) 3D reformatted image showing the planned implant which will cover the defect totally. (d) Intraoperative photo showing extended bicoronal incision showing the PSI fixed to the zygoma arch remnant (e) Postoperative view showing restored facial asymmetry. (f) Axial CT cut showing in-place PSI "white arrow" with minimal difference from the other side.

Discussion

The goal of this study was to assess the effectiveness and efficiency of VSP in managing different types of maxillofacial trauma patients, the advantages, and disadvantages of VSP, and the accuracy of 3D measures as a preoperative planning tool.

In this study, 30 consecutive patients with different types of CMF trauma were included. Participants' age ranged from 19 to 51 years. Most patients were males (73%). As regards the chronicity, the majority of cases had recent road traffic accident, followed by old fracture and then tumours. Regarding the type of trauma in our study participants, the most common type of trauma was orbital walls fracture followed by and ZMC fracture and frontal bone fracture, respectively while the least types of traumas were LE forte I, LE forte III, LE forte II, NOE, tumours, and orthognathic cases.

In the present study, the actual OT after VSP was significantly lower than the expected time by traditional methods (p =0.008) which came in line with many previous studies [7-16]. The witnessed decrease in OT could be clarified by preoperative proper surgical planning of the exact PSI shape, size and site of osteotomies to be performed. Immediate insertion after exposure had a value as no long time was spent for reshaping was necessary.

In a recent systematic review and meta-analysis by Pablo *et al.* [8], twelve articles were included representing 277 patients in the CAD/CAM group and 419 patients in the conventional group. CAD/CAM was associated with 65.3 fewer minutes of OR time (p < 0.0001). Also, in their retrospective study, Park *et al.* [11] measured the time of the conventional surgical planning (CSP) and VSP in orthognathic surgery and to compare them in terms of OT. The investigators concluded that the time investment in VSP in this study was significantly smaller than that in CSP.

However, in a single-center retrospective study designed by Bartiera *et al.* [17] found that There was no significant difference in surgery time between the traditional freehand reconstruction group and the 3D group using VSP, most likely because too many parameters besides the use of cutting guides affect surgery time (e.g., unilateral or bilateral neck dissection, mandibulectomy for cancer or osteoradionecrosis or malformation, longer neck dissection time in cases of prior irradiation, etc.). Therefore, it has been stated that the time savings should be weighed against the hour-long additional time required to complete the preoperative virtual modelling session. Therefore, if time savings were a measure of recouping the additional cost of the CAD/CAM approach, the total OT should not differ from that of the traditional technique [18].

According to our findings, there was no significant difference between the actual number of incisions used after VSP using CAD and computer aided manufacturing and the expected number of incisions that is used in the traditional methods. Similarly, Levine *et al.* [19] had been using 3D facial analysis and VSP in 70 CMF reconstructive and ablative cases and recorded that because the precision of this technique was shown to be nearly flawless, this had also allowed performing minimal incision approaches for even very large resections.

Noteworthy, the current study showed that 3D mean deviation was 0.105±0.198 mm which could be considered as marginal deviation. Moreover, the prominent edge of the implant could not be felt by the patients and no pain with maximum jaw opening was observed at follow-up visits reflecting the accuracy of the reconstruction and therefore more satisfactory outcomes.

A slightly higher error was reported by Maglitto *et al.* [9]. The 3D volume overlap study resulted in an estimated standard deviation of 5,496 mm (range from 1,966 to 8,004 mm). In their case series, Khashaba *et al.* [20] found a mean difference (SD) of 0.0373 (0.3036) mm and a median difference of 0.0809 mm. In contrast, De Maesschalck *et al.* [21] found no statistically significant difference between the control and test CAS groups for either linear or angular measurements, indicating that both approaches can yield equivalent accuracy.

In this study, the anatomic outcome was measured, and results was obvious. Majority of patients had perfect anatomic reduction (86.67%), while only 4 patients had basic anatomic reduction with no cases with non-anatomic reduction which also agree with Shakya *et al.* [22].

In our study, in terms of safe operation outcome, the complication rate was recorded to find any of the possible complications. The results were that scar alopecia, ectropion, temporary unilateral temporal branch of facial hypothesia, seroma, or limited wound dehiscence occurred in 3.3% patients, while temporary infraorbital hyposthesia was recorded in 6.7% patients. Minor complications were also reported Saad *et al.*, [23] and Khashaba *et al.* [20]. Thus, we can conclude that the role of VSP in decreasing the complications rate is evident which encourage surgeons to safely use these techniques.

According to reports, one of the possible constraints of VSP CAD/CAM technology is that it is pricey, resulting in extra expenditures for patients. Nevertheless, as several studies have said, because the benefits of VSP CAD/CAM are qualitative in nature, the technology has the ability to reduce problems and patient morbidity; hence, these enhanced outcomes contribute to balance the higher expenses [24, 25]. Ayoub *et al.* [26] concurred, stating that although the immediate cost of the CAM/CAD-assisted surgery was significantly higher, this would be offset in the long run by the decreased incidence of postoperative problems and the decrease in OT. Tarsitano *et al.* [27] conducted a cost analysis and determined that the institutional cost per minute of treatment in Italy was €30, but the overall cost of 3D-assisted surgery was €3500 (compared to $500 for traditional surgery). However, the patient saves €3,450 because to the shorter OT and hospital stay, therefore the expense is offset. However, the cost of 3D-printing technology is typically described as extremely costly [28, 29]. King *et al*. [30] discovered that the total operating expenses for patients treated with conventional procedures were $2306.45±212.44, but the total operating costs for patients treated with CAM/CAD technologies were only $698.00±30.35 ($p$<0.0001).Willinger *et al*. [31] found that conventional surgery and VSP costs were in similar ranges. Contrasted this, Fatima *et al*. [32] highlighted that VSP has upfront expenses that do not necessarily translate into downstream reduction in complications or improved outcomes.

The points of strength in this study include: the study topic and research questions are considered relatively new advanced field in our institution. We could find more detailed and variable outcome measures, these measures included intraoperative outcomes like OT and number of incisions. Moreover, postoperative detailed measures including accuracy difference measure, esthetic outcome either subjective or objective, anatomical outcome, safe operation outcome and functional outcome. The study was matched to the worldwide directions towards the digital transformation in all fields of research.

However, this study has some limitations such as lack of a control group and the relatively small number of enrolled cases, but the sample size was calculated upon the actual rate of these cases in our concerned institutes. Also, cost-effectiveness of VSP versus traditional methods were not investigated from economic perspective. Therefore, future research with larger sample size is needed to determine if this technology improves overall patient outcome along with investigating the economic advantages and disadvantages of VSP utilization.

Conclusion

Based on the previous data analysis, VSP in maxillofacial surgery has the potential to offer wide range of modern practice with better outcomes and it is considered a transitional step from traditional to digital surgery's practice. The advent of digital surgery has brought a novel solution to these issues. Surgical operations no longer rely solely on the subjective opinion of the surgeon; rather, digital technology in the surgical sector is utilised to develop accurate medical care.

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Conflict of Interest: Nil

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