Original Article

Comparative Study of Orbital Volume Reconstruction Using Stereolithographic Model Versus Free Hand Orbital Titanium Meshworks in Unilateral Orbital Floor Fracture: (A retrospective study)

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ABSTRACT

Background: Orbital blow out fracture can alter cavity dimensions and position of intra-orbital contents. Anatomical reduction and reconstruction of the orbital fracture is important for preventing latter complications. Introduction of medical software for virtual surgical planning and printing of stereolithographic (STL) models, allows the clinician to pre-bent the titanium orbital meshwork preoperatively reproducing accurate osseous anatomy. This reduces the risk of free hand orbital meshwork (FOM) malposition, poor anatomical contour and trauma to soft tissues.

Aim of the study: The aim of this study was to compare the orbital volume when using (STL) model versus (FOM) in the treatment of patients with unilateral orbital floor fracture.

Materials and Methods: Sixteen patients were included in this study. Chief complaint was orbital facial asymmetry related to an accident. Patients were divided into two groups, eight patients in each group. Group I was treated via (STL) model and group II with (FOM). Orbital volume ratio (OVR) then differential volumetric percentage were calculated for both groups. *P* value < 0.05 was considered significance.

Results: Measurements of orbital volume comparing the repaired side to the normal side; of group I revealed non-significant difference, while in group II revealed significant difference. Measurements of orbital volume comparing group I and group II revealed significant difference.

Conclusion: The application of (STL) technology in a unilateral orbital cavity reconstruction gives a good understanding of the anatomical state of the injured orbit.

Key Words: Orbital floor fractures, Orbital reconstruction, Orbital titanium meshwork, Orbital volume, Stereolithographic model technology.

Received: 26 April 2021, **Accepted:** 21 August 2021.

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ISSN: 2090-097X, April 2021, Vol. 12, No. 2

INTRODUCTION

Orbital fractures account for approximately 40 % of craniofacial trauma. There is a higher incidence of orbital floor fractures (blow out fractures) occurrence in orbital trauma due to the presence of infraorbital groove and canal[1 - 4]. Blow out fractures can alter cavity dimensions and position of intra-orbital contents, resulting in diplopia, enophthalmos, and visual acuity disturbances[4]. Anatomical reduction and reconstruction of the orbital fractures are important for preventing latter complications. Introduction of medical softwares for virtual surgical planning and printing of stereolithographic (STL) models, allows the clinician to pre-bent the titanium orbital meshwork preoperatively reproducing accurate osseous anatomy. This reduces the operative time required, risk of free hand orbital meshwork (FOM) malposition, poor anatomical contour and trauma to soft tissues due to multiple insertions during trimming and adaptation of the (FOM)[1].

The aim of this study was to compare the orbital volume when using (STL) model versus (FOM) in the treatment of patients with unilateral orbital floor fracture.

MATERIALS AND METHODS

Study design and sample:

Sixteen patients (nine males and seven females) who attended oral and maxillofacial surgery department at Ahmed Maher Teaching Hospital (Cairo, Egypt) from March 2017 to March 2019 were included in this study. Chief complaint was orbital facial asymmetry related to motor vehicle collision, assault, industrial accident and slip down and fall. All patients were consented about the research and randomly divided into two groups, eight

DOI: 10.21608/omx.2021.74145.1119

patients in each group. Group I (Study group) was treated via pre-bent titanium mesh using (STL) model and group II (Control group) with (FOM).

Data collection method:

The demographic and clinical data were collected from the patients' charts: age, gender, etiology and the side of the orbital floor fracture (Table 1).

Preoperative Preparation and Virtual Planning Technique:

Preoperative multi-slice CT scan was requested for each patient with a slice thickness of 0.5 mm (Figures 1 and 2). In all patients, Digital Imaging and Communication in Medicine (DICOM) files were transformed into 3D bony reconstruction virtual model. The optimum orbital floor contour in the injured side was created by mirroring and overlapping the uninjured side to the area of interest using software (Mimics V. 19 Medical V. Materialize, Leuven, Belgium). The final model was printed using the technology of (3D) printer (pursa i3). Then, the (STL) model was fabricated and prototyped using polylactic acid (PLA). The models were used for preoperative bending of the orbital floor meshwork to bridge the orbital floor fracture. Then pre-bent titanium mesh was autoclaved before surgery[1].

Table 1: Summary of the demographic data of the subjects:

Group	Patient	Age	Sex	Mechanism Of injury	Side affected	Time to repair (days)	Side of the orbits involved	Retro bulbar	The mean operation time (minute)
I	1	74	male	MVC	Right	5	Inferomedial	NO	100
	2	53	female	MVC	Right	8	Inferior	NO	140
	3	54	male	Fall	Left	7	Inferomedial	Yes	155
	4	40	male	assault	Right	4	Inferior	Yes	140
	5	44	female	MVC	Left	7	Inferior	NO	135
	6	26	male	I A	Right	6	Inferior	NO	90
	7	22	female	MVC	Left	10	Inferomedial	Yes	125
	8	28	male	MVC	Right	8	Inferior	NO	80
II	1	35	female	Slip down	left	7	Inferior	Yes	135
	2	55	male	MVC	Left	6	Inferomedial	NO	145
	3	68	female	MVC	Right	4	Inferomedial	Yes	85
	4	52	female	assault	Right	8	Inferior	Yes	120
	5	54	male	IA	Left	5	Inferomedial	Yes	140
	6	34	male	MVC	Left	8	Inferior	NO	155
	7	24	female	assault	Right	7	Inferomedial	Yes	110
	8	40	male	MVC	Left	8	Inferomedial	NO	140

MVC, motor vehicle collision.
I A, industrial accident.
n = 16 subjects, n = 16 orbital fractures.
The *p*-values were computed using Wilcoxon signed ranks tests for paired comparisons.

(A) (B) (C)

Figure 1: Photoradiograph showing preoperative C T of right sided orbital floor fracture (Case no.(4), group (I)):
(A): Axial view. (B): Coronal view. (C): Three dimensional view.

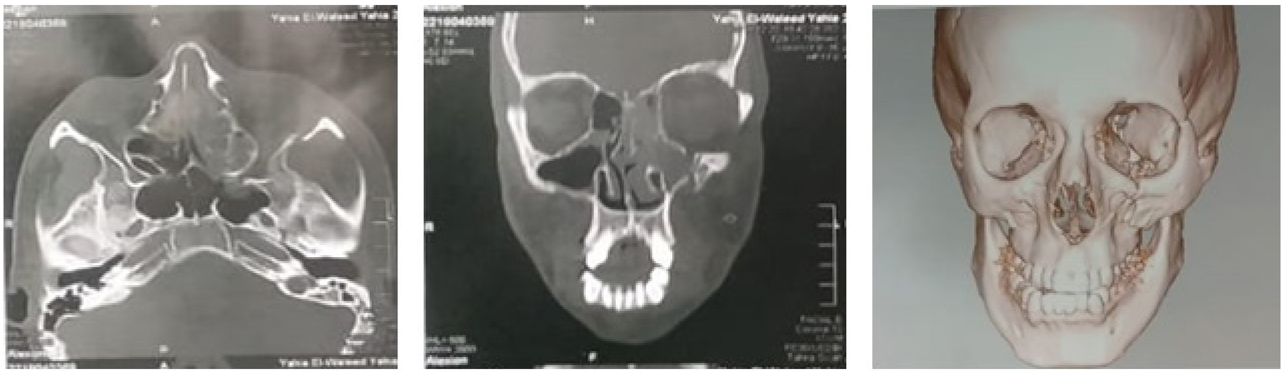

Figure 2: Group (II): Photoradiograph of preoperative C T showing fracture of left sided orbital floor (Case no.(2), group (II)): (A): Axial view. (B): Coronal view. (C): Three dimensional view.

Surgical Procedures:

The fracture site was approached using a subcilliary approach after infiltration of the inferior orbital rim subcutaneously by a local anaesthetic with vasoconstrictor*, traction suture was performed by a 40- black silk suturing material.

* Articaine HCL 4% with epinephrine 1: 100.000 (Septodont, by Novocol Pharmaceutical of Canada, Inc.).

The cornea was lubricated using Oxytetracycline Hydrochloride and Polymyxin B Sulfate Ophthalmic Ointment * ophthalmic ointment. All patients received a prophylactic dose of intravenous Ceftriaxone** 1 gm intraoperatively, which was continued by one tablet 1000 mg (1 gm) amoxycillin 875 mg combined with clavulanic acid 125 mg antibiotic*** which was prescribed every 12 hours for 7 days postoperatively. The incision was made 2 millimeters below and parallel to the lower eyelash with a no.15 scalpel, initially transecting the skin just beneath the eyelashes, then dissecting superficial to the orbicularis muscle till 2 to 3 mm below the tarsal plate. Then orbicularis occuli muscle was incised and then a combined "skin and muscle" flap was raised to the inferior orbital rim. An incision is then made on the anterior aspect of the orbital rim to avoid damage to the septum. Subperiosteal dissection was carried out with freer periosteal elevator and a malleable retractor was used to retract the orbital content to view the orbital fracture. After full exposure, the herniated orbital contents were released carefully from the fracture lines. The orbital rim was reduced and fixed with a miniplate.

In group I, pre-bent meshwork was screwed and fixed to the orbital rim (Figure 3). While in group II; the titanium meshwork was trimmed down according to a malleable template then was adapted along the reduced fractured orbital floor (Figure 4).

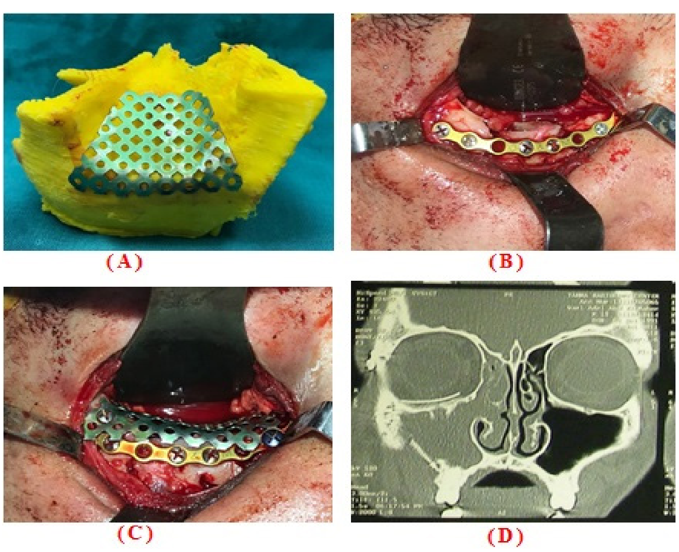

Figure 3: Photograph showing (Case no.(2), group (I)), (A) Preoperative bending of orbital meshwork {SLG. (B) Subciliary incision of the right side , reduction of orbital floor and rim fractures and fixation with miniplate. (C) Adaptation and fixation of orbital meshwork. (D) Postoperative photoradiograph of C T, coronal view, showing adaptation of orbital meshwork.

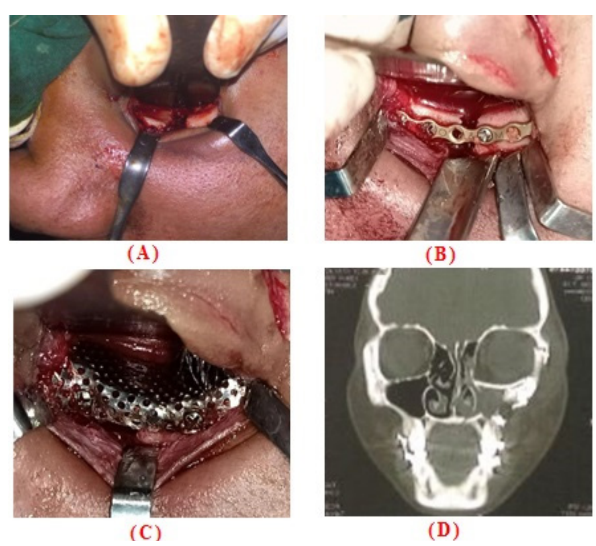

Figure 4: Photograph showing, (Case no.(1), group (II)) (A) Subciliary incision of the left side and exposure of orbital floor and rim fractures. (B) Intraoperative reduction and fixation of orbital rim by miniplate. (C) Intra-operative adaptation and fixation of free hand bent meshwork. (D) Photoradiograph of postoperative three dimensional C T, coronal view showing meshwork fixation.

In both groups forced duction test was performed to confirm that the impinged orbital contents had been released. Periosteum was sutured using 4 / 0 vicryl sutures, skin was closed using 4 / 0 prolene sutures.

* Terramycin : Zoetis Incm US.

** Ceftriaxone: Sandoz GmbH for Hospira ,Inc.Lake Forest, IL.60045, USA.

*** Hibiotic: Amoun pharmaceutial Co. S.A.E. – Egypt.

Postoperative Calculation of Orbital Volume:

Postoperative multi-slice (CT) scan was requested for each patient in both groups. The data from these scans, stored in standard (DICOM) format and were subsequently imported in the Maxillo software (Stratovan Corporation, Sacramento, CA,U. S. A.). The software presents the data in standard axial, coronal, sagittal views and 3-dimensional reconstructions. Orbital volume was calculated for the uninjured side, by placing virtual 3-dimensional anatomical markers (fiducials) on 6 predefined anatomical landmarks (roof of the external auditory canal, optic canal, superior orbital rim, inferior orbital rim, lateral orbital rim, and medial orbital rim).Once the landmarks have been placed, an automated orbital volume is generated. For the injured side the same technique of measurement was used to calculate the orbital volume based on the orbital and implant borders (5 - 7) (Figure 5).

- Orbital Volume Ratio (OVR) = Injured orbital cavity volume /Uninjured orbital cavity volume.

- Differential volumetric percentage = OVR x 100 .

Statistical analysis:

The collected data were revised, coded, tabulated and introduced to computer using SPSS 22.0 for windows. Data were presented, and suitable analysis was done according to the type of data obtained for each parameter.

Descriptive statistics include, mean, standard deviation (± SD) and range for numerical data were performed. Analytical statistics by using paired sample t-test, assess the statistical significance of the difference between study and control group. When P-value > 0.05, it means non-significant (NS), $P \leq 0.05$ means significant (S) and $P \leq 0.01$means highly significant (HS).

RESULTS

The patients (nine males and seven females) in both operative groups were aged between 28 and 74 years old (mean, 43.94 ± 15.04). Nine patients had infero-medial blowout fractures. The other seven had orbital floor fractures. The causes of fractures were recorded. (Table 1). Operations were performed at an average of 6.75 days after having been injured (range, 4 to 10 days). The mean operation time was 124.69 ± 23.75 minutes (ranging from 80 to 155 minutes), and the follow-up lasted for 12 weeks. Preoperatively, seven patients had diplopia. Six patients had enophthalmos. Six presented with retrobulbar hemorrhage.

In this study postoperatively, as regard to group I, the mean orbital volume in the injured side was 30.33 ± 0.59 cc (ranging from 29.20 to 31.11 cc). While in un-injured side was 30.21 ± 0.65 cc (ranging from 28.98 to 31.09 cc). P value = 0.27 revealed that non-significant difference between both sides. (P-value > 0.05) (Table 2).

In group II, the mean orbital volume in the injured side was 32.29 ± 1.66 cc (ranging from 29.02 to 33.93 cc). While in un-injured side the mean was 30.60 ± 0.71 cc (ranging from 29.84 to 31.98 cc). P = 0.02 revealed that significant difference between both sides. (P-value < 0.05) (Table 3).

In comparing between both groups the postoperative differential volumetric percentage in group I was 100.41 % ± 0.79 (ranging from 98.73 % to 102.21 %). While in group II, was 105.54 % ± 5.19 (ranging from 93.78 % to 111.47 %). P value = 0.03 revealed that, there is a significant difference between both groups (p-value < 0.05) (Table 4).

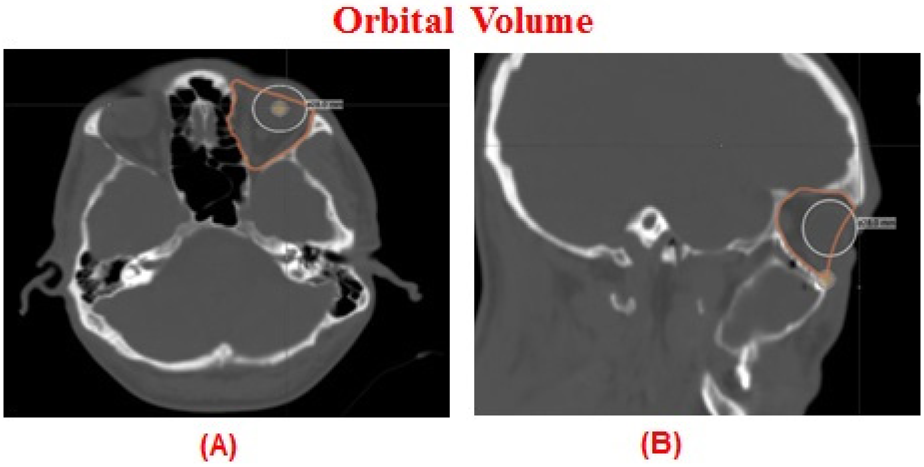

Figure 5: Photoradiograph showing postoperative:
(A): Axial view. (B): Sagittal view:
- (Red outlines) used to calculate the orbital volume.
- (White circle) indicating the globe.

Table 1: Wilcoxon signed-rank test results for comparison between the closest distance of the implant to IAN in both virtual and actual implants in all the studied cases:

Minimal distance (mm)	Mean	SD	Median	Range	P value
Virtual implants	1.7	0.56	1.75	1 – 2.5	0.027*
Actual implants	0.72	0.25	0.7	0 - 1	

* Statistically significant at $p \leq 0.05$.

Table 2: Summary of postoperative orbital volume measurements and Differential volumetric percentage for unilateral fractures in stereolithographic meshwork group (group I):

Group	Patient	Average volume of injured side(cc)	Average volume of Un-injured side (cc)	Postoperative differential volumetric percentage	P- Value
I	1	30.3766	30.3912	99.9520 %	0.27
	2	30.4932	29.8344	102.2082 %	
	3	30.9474	30.7754	100.5589 %	
	4	30.1498	30.5375	98.7304 %	
	5	31.1117	31.0914	100.0653 %	
	6	30.2984	30.0947	100.6769 %	
	7	30.0731	29.9667	100.3550 %	
	8	29.2001	28.9799	100.7598 %	
Mean		30.33 ± 0.59	30.21 ± 0.65	100.41 ± 0.97 %	

Applying paired samples t test to measurements of orbital volume comparing the corrected side to the normal side of group I revealed non-significant difference. (p- value > 0.05).

Table 3: Summary of postoperative orbital volume measurements and Differential volumetric percentage for unilateral fractures in free hand meshwork group (group II):

Group	Patient	Average volume of injured side (cc)	Average volume of Un-injured side(cc)	Postoperative differential volumetric percentage	P- Value
II	1	32.3092	30.0349	107.559 %	0.02
	2	31.0041	29.8447	103.8848 %	
	3	29.0153	30.9387	93.7831 %	
	4	33.9294	31.9841	106.082 %	
	5	33.9431	30.4512	111.4671 %	
	6	32.8222	30.5711	107.3634 %	
	7	33.3092	31.0194	107.3818 %	
	8	32.0178	29.9876	106.7701 %	
Mean		32.29 ± 1.66	30.60 ± 0.71	105.54 ± 5.19 %	

Applying paired samples t test to measurements of orbital volume of group II patients comparing the injured side to the normal side revealed significant difference. (p- value < 0.05).

Table 4: Summary of postoperative orbital volume measurements and differential volumetric percentage for unilateral fractures in both groups:

	Group I postoperative differential volumetric percentage	Group II postoperative differential volumetric percentage	P - Value
Mean	100.41± 0.97 %	105.54 ± 5.19 %	0.03

Applying paired samples t test to measurements of orbital volume comparing group I and group II patients revealed significant difference. P- Value = 0.03 (< 0.05).

DISCUSSION

Reconstruction of orbital defects is a challenging procedure for surgeons due to the anatomical complexity, narrow surgical view, and critical contents in the vicinity[7]. Improper correction of the orbital floor alone or in combination with incorrect zygomatic fracture segment alignment will lead to an increased orbital volume. Moreover, resulting in many complications such as postoperative diplopia, inferior orbital nerve function defects and enophthalmos[8].

Clinical experience shows that, even with proper reconstruction of the orbital floor, patients can still exhibit positional deficits relative to the contralateral globe. This may be true despite free hand orbital titanium mesh overcorrection[5].

Retrobulbar fat represents approximately 70 % of the orbital volume; therefore, displacement and atrophy of periorbital fat following orbital floor blow out fracture will cause posterior globe displacement (enophthalmos). Causes of fat necrosis and atrophy include impingement and hematoma with the acute fracture and/or extensive injury and scarring of orbital fat with multiple recurrent procedures and manipulation. Various studies showed an up to 5% of retrobulbar fat reduction and globe recession due to scarring within the healing process[9, 10]. The correlation of enophthalmos and orbital volume increase was shown to be linear by Schuknecht *et al.*[11].

Stereolithographic technique involves (CT) scanning, (CT) data processing and virtual (3D) model creation, and model production by stereolithographic model technology. Virtual 3D modeling can determine the location and size of the orbital cavity defects and the anatomy of individual patients, and preoperative virtual surgical planning may enable greater accuracy in reconstructed contour. Three-dimensional measurements are used to determine the variations in the orbital cavity volume, predict potential enophthalmos, even at the early stage of injury, and help determine the operability[12 - 14].

Orbital cavity reconstruction is an ideal target of the (STL) technique owing to its anatomical complexity, and many researchers have applied a (STL) model to reconstruction[15 - 18]. Gordon *et al.*[19] reported that the use of a pre-bent titanium implant, considering the three-dimensional orbital anatomy, led to an effective reconstruction. On the other hand, there is no standard method that can provide a consistent outcome, and both a clinically favorable outcome and an ideal type of anatomical restoration may require a good understanding of the individual anatomy of each patient.

In this study, STL model of the orbital cavity was used for preoperative surgical planning. Accurate implant positioning using (STL) resulting in the mean (OVR) was 100.41 % ± 0.97 (ranging from 98.73 % to 102.21 %) compared to 105.54 % ± 5.19 (ranging from 93.78 % to 106.08 %) in case of (FOM) postoperatively ($P = 0.03$).This revealed that, there is a significant difference between both groups (p-value < 0.05). Those finding are in agreement with Kozakiewicz *et al.*[2] who proved the role of building anatomical models, on the basis of CT studies, that can be used in the repair of orbital floor fractures.

From our recommendation in this study, counteracting fat reabsorption rate and perioperative edema, we advise a slight overcorrection of 2 to 3 mm. Post-surgical long term serial clinical examination (eg. Hertel measurements) and volumetric three-dimensional imaging may certainly bring light into this query in the future[20].

This study has its limitations; the length of time required to build model, the cooperation required between a number of people in different locations with additional costs; and the use of this method in panfacial fractures is challenging because it is difficult to find any stable orbital margins for virtual planning of the model and to establish an accurate position for the pre-shaped plates[5].

In conclusion, the application of (STL) technique in a unilateral orbital cavity reconstruction gives a good understanding of the anatomical state of the injured orbit, predicts the potential outcome through three-dimensional measurements and helps determine the operability. This technique is effective in restoring the orbital cavity volume through optimal implant positioning. This may help bring about a clinically favorable outcome. STL technique is expected to ease the difficulty of orbital reconstruction by producing implants through computer- aided design applicable to the human body.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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