Orbital Volume Evaluation post Orbital Fractures Restoration

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Abstract

Background: The orbits are bony structures of the skull that house the globe , extra ocular muscles (EOM), nerves, blood vessels, lacrimal apparatus and adipose tissue. Each orbit protect the globe, while the supportive tissues therein allow the globe to move in three dimensions (horizontal –vertical-rotational).

Objectives: Evaluation of orbital volume after orbital fractures reconstruction by software orbital volume measurement using CT scan.

Patients and methods: This study was conducted on 20 patients with a unilateral orbital blowout fracture treated surgically at Department of Plastic and Reconstructive Surgery in AL-Azhar University Hospitals from October 2018. To October 2019 and followed for 3 months were identified and included in this study.

Results: 5% of patients had positive limitation of EOM and 90% of patients were good Pt. acceptance post-operative. 5% of patients were dystopia post-operative, all of patients had no infection, enophthalmouse or extrusion.

Conclusion: We must exert great effort to prevent occurrence of these injuries through a joint cooperation with civil society through the dissemination of culture and means of safety on the highways. Rules and basics of craniofacial osteosynthesis must be known to craniofacial surgeon starting from wiring osteosynthesis.

Keywords: Orbital Volume, Orbital Fractures Restoration, osteosynthesis, CT scan.

Introduction

Clinical presentations associated with orbital fractures vary in severity depending on the presence of ocular trauma and the location of the fracture. Symptoms include pain with motility, diplopia with limitation of motion, hypesthesia and trismus. Clinical signs include ecchymosis, crepitus, bone step-off, ptosis, enophthalmos and strabismus. Diplopia and limitation of ocular movement are caused by various conditions. These include orbital hemorrhage and edema, muscular edema or hemorrhage, cranial nerve palsy and entrapment of soft tissue or muscle itself [(1)].

The approach to the fracture site depends upon the type of injury, surgeon experience and available equipment. Subciliary, subtarsal, transconjunctival, transwound, transscar, and bicoronal incisions are the most commonly utilized [(2)].

In a case of ZMC assessing for the accuracy of reduction at the completion of the case can be difficult. In general, the most accurate area to check for adequacy of reduction and prevent future complications is the ZS suture along the lateral orbital wall. Rather deceivingly, the infraorbital rim and zygomaticomaxillary buttress (ZMB) can appear relatively well aligned while there is still significant lateral rotation of the malar complex in its posterior component. If one examines the lateral wall or slides an elevator here, misalignment will easily be made known by a step-off in this region. Every effort should be made to over-rotate the posterior aspect of the fragment in cases of uncertain fragment position to cause relative compression of the orbital contents [(3)].

Furthermore, orbital volume measurements can be considered important for treatment planning by providing an accurate estimation of orbital implant volume, which is necessary for optimal reconstruction of enophthalmos. However, several problems can arise when CT scans are used to measure the orbital volume with standard computer-based programs. Difficulties in measuring the exact orbital volume include: (1) bony orbital cavities, which are roughly the shape of a quadrilateral pyramid with its base directed forward and laterally, not exactly located horizontally or perpendicularly to the axial or coronal plane, (2) bony defects, which in some locations can introduce errors in measurement (eg, orbital apex, inferior orbital fissure, superior orbital fissure, lacrimal sac and

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orbital base with errors caused by including the missing anterior wall of the orbit), (3) interoperator or intraoperator variability and (4) errors caused by the use of different measurement techniques and software programs. Recently, with the development of 3-D software programs, it became easier to measure the orbital volume [4].

Ploder *et al.* [5] in their experimental studies using orbital fractured models on dried skulls, demonstrated that both 2-D and 3-D measurement methods are accurate for assessing the fracture area and herniated tissue volume of isolated blowout fractures, but they found that 2-D–based calculations involved less processing time and fewer errors.

Aim of the study

Evaluation of orbital volume after orbital fractures reconstruction by software orbital volume measurement using CT scan.

Patient and methods

This study was conducted on 20 patients were identified and included in this study. They had a unilateral orbital blowout fractures that were treated surgically at Department of Plastic and Reconstructive Surgery in AL-Azhar University Hospitals from October 2018 to October 2019 and followed for 3 months. This research adheres to the tenets of the Declaration of Helsinki.

Inclusion criteria

1. Age: adult (above age of sixteen).
2. Sex: both sex are included.
3. Acute orbital fractures less than 1 mounth ago.
4. Unilateral orbital fracture.

Exclusions criteria

1. Bilateral orbital wall fractures.
2. Other pre pathological conditions that affect the orbital volume (thyroid-associated, ophthalmopathy and orbital tumor).

Ethical considerations

The study protocol was approved by local Ethical Committee of AL-Azhar University, Faculty of Medicine. All patients were informed about the study and their signed written consent for participation in the study was obtained. Patient confidentiality and right to withdrawal at any time were ascertained.

All patients were submitted to pre-operative and post-operative evaluations:

1. **Pre-operative patient evaluations:**
2. History**,** physical examination and general examination.
3. Local orbital examination.
4. **Neurosurgical consultation:** Preoperative neurosurgical evaluation of post-traumatic brain contusion and intracranial injuries.
5. **Radiology:** Computed Tomography: axial view, coronal view, sagittal view, and 3dimentions. Software assessment of fractured side with evaluation to the intact contralateral side.

Operative strategy:

Timing of surgery: Surgical treatment was performed after the onset of trauma depending on the amount of swelling. If there was no contraindication for surgical intervention at day of admission the patients were operated without any delay.

Photographic documentation: All patients were submitted to standard photographic documentation in all facial views, A-P, Oblique and lateral views.

Operative steps:

All cases were treated under general anesthesia with naso-tracheal intubation.

Face was painted with povidone-iodine. Towels and drapes were applied to expose the surgical area. Local infiltration at the fracture site was done using 2% lignocaine with 1:80000 adrenaline for vasoconstriction.

Fractures were exposed through a transconjunctival incision for inferior orbital wall fractures, and through a transcaruncular incision for medial orbital wall fractures. Herniated orbital contents were repositioned by a periosteal elevator, a suction tip, and a malleable retractor. Orbital wall defects were reconstructed using orbital implants by insertion under periosteam at fracture sites.

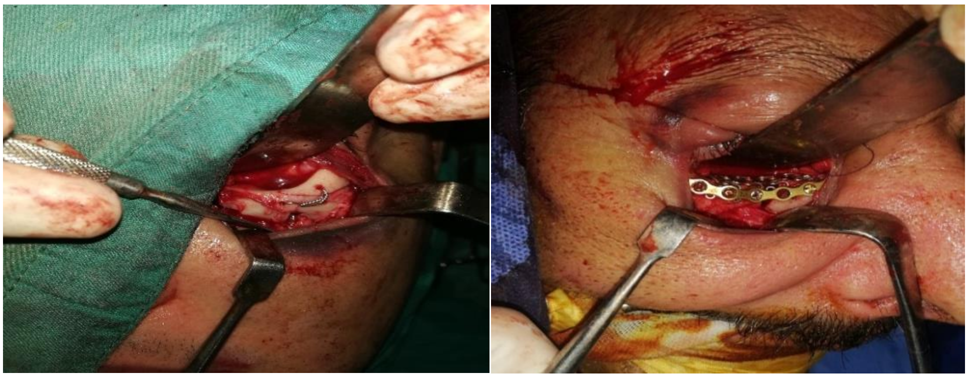

Fig. (1): Exposure and reconstruction of inferior orbital wall by titanium mesh.

After this procedure, a forced duction test was performed to ensure the absence of restriction. During surgery pupil size was checked for optic nerve compression. To reduce orbital tissue swelling, methylprednisolone (250 mg) was administered intravenously during surgery, after surgery, and the day after surgery, respectively. Thereafter, methylprednisolone was given orally and tapered.

Postoperative recovery:

All cases were recovered smoothly and transferred to inpatient ward and monitored for general signs (pulse, blood pressure and temperature), patient air way and eye care.

Post-operative follow up:

During the first month after surgery, patients were observed weekly and then monthly. For all the 20 patients, the observation period was a three months.

Degrees of clinical improvement were assessed by grading clinical signs at 1, 2, and 3 months after surgery as follows: diplopia within the central 20° visual field as grade III, diplopia between 20° and 40° visual fields as grade II, diplopia only on the periphery beyond the 40° visual field as grade I and 'no diplopia' was defined as the absence of diplopia.

Extraocular movement limitation was assessed using the position of corneal reflection using pen light illumination of the cornea with the eye looking in the direction of extra-ocular muscle action.

CT examinations were performed on all study subjects before surgery, immediately after surgery, and at final follow up.

Locations and ranges of orbital wall fractures and strangulation of orbital soft tissues or extraocular muscles were identified before surgery by CT.

Locations of orbital implants and reductions of fractured orbits and herniated orbital tissues were identified immediately after surgery and orbital wall reconstruction maintenance was assessed at final follow up.

A CT scanning system, Mimic Materialise (ver.20, Varian Medical System, Inc.) was used to measure volumes of fractured and contralateral orbits before and after surgery (early post-operative and late post-operative). In each case, bony orbital and herniated orbital tissue areas on sections were measured using a drawing cursor freehand. Drawn orbital contours were then reconstructed as three-dimensional images and orbital volumes were calculated automatically.

Early post-operative follow up visit: On the day 1, 3 and 7 post-operative for:

- Pupil reaction, extra ocular movement.
- Correction of enophthalmouse and diplopia
- Globe position.
- Possible early complications.
- Periorbital hematoma.
- Diplopia.
- Enophthalmouse.
- Orbital dystopia.
- Delayed wound healing.
- Infections.

Software assessment of fractured side with evaluation to the intact contra lateral side. After 1 weak.

Late post-operative follow up visit: On one and three month visit for:

- Possible late complications:

- Enophthalmouse.
- Orbital dystopia
- Ectriopion.
- Facial asymmetry.
- Ugly scars.

Software orbital volume assessment of reconstructed side with evaluation to the intact contra-lateral side and calculation of OVR%.

Statistical analysis:

Data were collected, coded, revised and entered to the Statistical Package for Social Science (IBM SPSS) version 20. The data were presented as number and percentages for the qualitative data and mean, standard deviations and ranges for the quantitative data. Parametric distribution and median with inter quartile range (IQR) for the quantitative data with non-parametric distribution. Independent t-test was used in the comparison between two groups with quantitative data and parametric distribution. Mann-Whitney test was used in the comparison between two groups with quantitative data and non-parametric distribution.

The comparison between more than two groups with quantitative data and parametric distribution were done by using One Way Analysis of Variance (ANOVA) test. Kruskall-Wallis test was used in the comparison between more than two groups with quantitative data and non-parametric distribution. Paired t-test was used in the comparison between two groups with quantitative data for before and after and parametric distribution. Wilxon Rank test was used in the comparison between two groups with quantitative data for before and after and non-parametric distribution. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following:

- P > 0.05: Non significant (NS)
- P < 0.05: Significant (S)
- P < 0.01: Highly significant (HS)

Results

Table (1): Demographic data

		No	%
Age	(20:30)	8	40.0%
	(31:40)	6	30.0%
	(More than 40)	6	30.0%
Sex	Female	4	20.0%
	Male	16	80.0%

This table showed that 40% of patients were between 20 and 30 years, 30% of them were more than 40 years, 80% of patients were males and 20% of them were females.

Table (2): Comparison between volume of non-fractured side pre-operative and volume of non-fractured side early post-operative

	Mean	SD	Parried T Test	
			r	p value
Volume of non-fractured side pre op.	21.195	1.65067	0.998	<0.001
Volume of non-fractured side early post	21.185	1.68125		

This table showed that there was statistically significant increase in volume of non-fractured side pre-operative in comparison with volume of non-fractured side early post-operative.

Table (3): Comparison between volume of non-fractured side pre-operative and volume of non-fractured side late post-operative

	Mean	SD	Parried t test	
			R	p value
Volume of non-fractured side pre op.	21.195	1.65067	0.998	<0.001
Volume of non-fractured side late post	21.125	1.66255		

This table showed that there was statistically significant increase in volume of non-fractured side pre-operative in comparison with volume of non-fractured side late post-operative.

Table (4): Comparison between volume of side pre-operative and volume of side early post-operative

	Mean	SD	Parried t test	
			r	p value
Volume of fractured side pre op.	23.47	1.60496	0.953	<0.001
Volume of fractured side early post	21.445	1.71258		

Table (4) showed that there was statistically significant increased volume of side pre-operative in comparison with volume of side early post-operative.

Table (5): Comparison between volume of fractured side pre-operative and volume of fractured side late post-operative

	Mean	SD	Parried t test	
			r	p value
Volume of fractured side pre op.	23.47	1.60496	0.957	<0.001
Volume of fractured side late post op	21.785	1.69006		

This table showed that there was statistically significant increase in volume of side pre-operative in comparison with volume of fractured side late post-operative.

Table (6): Comparison between ages as regards volume of non-fractured side (pre-operative, early post-operative and late post-operative)

	(20:30)		(31:40)		(More than 40)		one way ANOVA	
	Mean	SD	Mean	SD	Mean	SD	F	p value
Volume of non fractured side pre op.	21.83	1.71	20.64	1.39	21.10	1.88	0.908	0.422
Volume of non-fractured side early post	21.83	1.78	20.64	1.41	21.07	1.89	0.880	0.433
Volume of non-fractured side late post	21.80	1.72	20.50	1.36	21.07	1.88	1.085	0.360

Table (6) showed that there was no statistically significant difference between age as regards volume of non- fractured side (pre-operative, early post-operative and late post-operative.

Table (7): Comparison between ages as regards volume of fractured side (pre-operative, early post-operative and late post-operative)

	(20:30)		(31:40)		(more than 40)		one way ANOVA	
	Mean	SD	Mean	SD	Mean	SD	f	p value
Volume of fractured pre op.	23.81	1.98	23.21	1.22	23.37	1.75	0.241	0.788
Volume of fractured side early post	21.69	1.74	20.41	1.38	21.10	2.03	0.963	0.402
Volume of fractured Side late post op.	22.00	1.71	20.77	1.34	21.45	2.03	0.920	0.417

This table showed that there was no statistically significant difference between ages as regards volume of fractured side (pre-operative, early post-operative and late post-operative.

Table (8): Comparison between sex as regards volume of non- fractured side (pre-operative, early post-operative and late post-operative)

	Male		Female		Independent t test	
	Mean	**SD**	**Mean**	**SD**	**t**	**p value**
Volume of non- fractured side pre op.	21.19	1.63	19.73	0.63	2.179	0.043
Volume of non- fractured side early post	21.18	1.65	19.65	0.60	2.249	0.037
Volume of non- fractured side late post	21.12	1.66	19.73	0.63	2.032	0.057

This table showed that there was statistically significant increase in male in comparison with female concerning volume of non- fractured side pre-operative and early post-operative.

Table (9): Comparison between sex as regards volume of fractured side (pre-operative, early post-operative and late post-operative)

	Male		Female		Independent t test	
	Mean	**SD**	**Mean**	**SD**	**t**	**p value**
Volume of fractured side pre op.	23.82	1.61	22.08	0.25	2.113	0.049
Volume of fractured side early post	21.44	1.70	19.58	0.59	2.116	0.049
Volume of fractured side late post op.	21.78	1.68	19.90	0.51	2.179	0.043

Table (9) showed that there was statistically significant increase in male in comparison with female regarding volume of fractured side pre-operative, early post-operative and late post-operative.

Discussion

Fractures of the orbit are common and challenging to manage. They deserve special consideration because surgical or observational management may result in compromise to vision and/or globe position [(6)].

We designed this study for evaluation of orbital volume after orbital fractures reconstruction by software orbital volume measurement using CT scan. This study was conducted on 20 patients with a unilateral orbital blowout fracture treated surgically at Department of Plastic and Reconstructive Surgery in AL-Azhar University Hospitals from October 2018. To October 2019 and followed for 3 months.

The study by **Scawn *et al.*** [(7)] was similar to our study. They reported that delayed surgery may still result in unsatisfactory outcomes, such as, fracture malunion, because of adhesion to adjacent tissues and fibrosis of soft tissues, which make delayed surgery more technically challenging. Clinical outcomes including diplopia, enophthalmos and infr-aorbital hypoesthesia were similar in early (≤ 14 days) and delayed (14 days) surgery groups. No significant OVR% difference was observed between the two groups immediately after surgery (P=0.891). However, the early surgery group showed better mean OVR% at final follow up (P=0.039). During the early post-traumatic period, enophthalmos may not be observed because of orbital soft tissue swelling, but in time it can be observed definitely because of fat necrosis and reduced soft tissue volume. For this reason, during the early post-traumatic period, it is difficult to decide whether surgery is indicated based on the extent of enophthalmos [(7)].

Ploder *et al.* [(5)] reported that 1.2 mm of enophthalmos was improved by a 1 cm^3 reduction of fractured orbits in 38 inferior wall fracture patients when orbital volume was measured using region-of-interest measurements taken from CT images.

Our study, similar to **Wi *et al.*** [(8)], failed to find a significant correlation between increased fractured orbit volume and enophthalmos before surgery. Mean enophthalmos before surgery was only 0.4 mm, presumably low level of enophthalmos was due to soft tissue swelling during the early post-traumatic period. Bony orbit and herniated orbital tissue volume measurements are useful when deciding whether surgery is indicated and for determining successful orbital wall fracture reconstruction [(8)].

Furthermore, temporal considerations regarding orbital wall fracture reconstruction rates were not investigated because orbital volumes were only measured before and after surgery. Accordingly, in the present study, we decided to measure orbital volumes at three time points (before surgery, immediately after surgery and at final follow up) using a three-dimensional imaging software program. Mimic Materialise (Ver: 20.0, Varian Medical System, Inc.) used in this study was originally used in the radiation and oncology fields to accurately measure organ volumes to determine appropriate dosimeters.

When a contour is drawn on orbital CT axial scans, it is drawn on the coronal plane and sagittal plane simultaneously and when the medium contour differs from that drawn by an observer, the program automatically compensates. This system allows an observer to accurately contour the orbit boundary and minimizes manual errors and it reconstructs orbital contours as three-dimensional images and calculates orbital volumes automatically **[9].**

In this study, we introduced the new formula to quantify the effect of orbital wall reconstruction by defining a new variable OVR%. Similar to **Wi *et al.*** **[8]** in previous studies, the effect of orbital wall reconstruction was evaluated by simply calculating volume differences or volume ratios between fractured and contralateral orbits before and after surgery **[10].** However, with those calculations, larger differences between the volumes of fractured and contralateral orbits before surgery may result in greater overestimations of the effect of orbital wall reconstruction. To address this limitation, we used OVR%, which provides a measure of how close the volume of the fractured orbit to the volume of contralateral orbit after surgery, and defined OVR% = (1-(A-B/B)) *100 (A = fractured orbit volume after surgery, B = contralateral orbit volume). They measured orbital volumes at three time points (before surgery, immediately after surgery, and at final follow up). Based on these measurements, we were able to calculate OVR% immediately after surgery and at final follow up, and examined relations between OVR% with respect to orbital implant type, orbital wall fracture location, and time elapsed between trauma and surgical intervention.

Wi *et al.* **[8]** used The Eclipse Treatment Planning System' (ver.13.0, Varian Medical System Inc.) and recommend that mean volume of fractured orbits before surgery was 23.01 ± 2.60 cm^3 and that of contralateral orbits was 21.31 ± 2.50 cm^3 . **Baek *et al.*** **[11]**, used the Somaris program to measure orbital volume. **Wi *et al.*** **[8]** mean normal orbit volumes were 24.51 ± 2.89 cm^3 for men and 21.59 ± 2.19 cm^3 for women. Our study closely related to **Wi *et al.*** **[8]** and we recommend that, the mean contralateral orbit volume pre-operative was 21.19 ± 2.40 cm^3 for men and 19.73±1.9 cm^3 for women.

Immediately after surgery, mean volume of fractured orbits was 21.44 ± 2.42 cm^3 for men, 19.58 ± 2.1cm^3 for women and that of contralateral orbits was 21.57 ± 2.52 cm^3 for men , 19.65 ± 2.1 cm^3 for women and mean volume of fractured orbits at final follow up was 21.78 ± 2.44 cm^3 for men & 19.9 ± 1.71 cm^3 for women. The mean volume of contralateral orbits was 21.13 ± 2.50 cm^3 & 19.73 ± 1.19 cm^3 for women. Mean volume of fractured orbit was significantly smaller immediately after surgery than that measured before surgery (P = 0.004).

Patients that underwent surgery within 14 days of trauma achieved better reconstruction rates at final follow up, which supports the need for early surgery.

Conclusion

Recently, it was noted that there is gradual increase in cases of maxillofacial trauma in Al-Azhar University Hospital (New Damietta) due to its geographical location near the international Coastal Highway. This shows the importance of the need for specialists in craniofacial surgery. We must exert great effort to prevent occurrence of these injuries through a joint cooperation with civil society through the dissemination of culture and means of safety on the highways. Rules and basics of craniofacial osteosynthesis must be known to craniofacial surgeon starting from wiring osteosynthesis.

Results of this study demonstrated:

- Importance of measurement of orbital volume pre-operative of fractured side and evaluation with intact contralateral side.
- We failed to find a significant correlation between increased fractured orbit volume and enophthalmos before surgery. Mean enophthalmos before surgery was only 0.4 mm, presumably low level of enophthalmos was due to soft tissue swelling during the early post-traumatic period. However, the

measurement of orbital volume after complete subside of edema showed that 0.87 mm enophthalmos was improved by a 1 cm^3 fractured orbit reduction.

- The diagnosis and treatment of orbital floor fractures bear great importance because they may result in enophthalmos and diplopia if not treated in a timely manner and with the appropriate construction material. This study showed that good prognosis in orbital floor fractures depends on accurate determination of the indications of surgery, early surgical intervention and selection of proper reconstruction.

In light of the results of the current study:

1- Pre-operative measurement of orbital volume of fractured side and evaluation with intact contralateral side for these reason:

- Determination of the difference of orbital volume between the fractured side and intact contralateral side.
- Measurement of orbital volume pre-operative (in acute and late cases) guide us to detect the site and size of orbital wall defect.
- Measurement of orbital volume pre-operative decrease the rate of post-operative complications (enophthalmouse & dystopia).
- In a case of sever comminuted orbital fracture we can use the intact side as mirror image for reconstruction.

2- Early fixation of orbital fracture for these reasons;

- Increased number of admitted cases of maxillofacial trauma in Al-Azhar University Hospital (New Damietta)
- Decrease in the overall cost of hospital stay
- Early return to work
- Patients that underwent surgery within 14 days of trauma achieved better reconstruction rates at final follow up, which supports the need for early surgery.

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