Original Article

Evaluation of orbital volume after orbitozygomatic complex fractures fixation: A radiographical study

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ABSTRACT

Background: Orbitozygomatic complex fractures are one of the most commonly encountered injuries of the craniofacial skeleton. The aim of this study was to implement the orbital volume as an objective evaluation modality for the assessment of the accuracy of unilateral Orbitozygomatic complex fracture fixation, by comparing the postoperative values with the contralateral normal side and the pretreated values.

Materials and methods: A retrospective radiographic, chart review was performed in order to investigate the primary outcome of the objective quantification of the accuracy of Orbitozygomatic complex fracture reduction utilizing orbital volume analysis. Comparing the postoperative orbital volume values with the preoperative, and the contralateral normal ones was set as the study secondary outcome, along with the percentage of changes in the orbital volume of unilateral Orbitozygomatic complex fracture treated patients. Data reliability was performed using Interclass correlation coefficient and Statistical significance was set at 5% level.

Results: Seventeen records met the inclusion criteria. While a statistically significant difference was found between the preoperative orbital volume values of the affected side and that in the normal unaffected side ($P < 0.001$), a statistically insignificant difference was encountered between the postoperative values and the control side ($P = 0.333$). An average percentage of decrease of 6.1% was reported in the postoperative records when compared to the preoperative ones, with a statistically significant difference ($P < 0.001$). The study reported high inter (ICC = 0.97) and intra (ICC = 0.97) observer reliability.

Conclusion: Orbital volume analysis offers a valid modality for the objective evaluation of the efficiency of Orbitozygomatic complex fracture management.

1. Introduction

The appearance of the Orbitozygomatic complex (OZC) fracture terminology is contributed to the fact that a fracture in the lateral side of the midface is not strict to anatomical boundaries, however, it involves the zygoma, maxilla and orbital structures.¹ Orbitozygomatic complex fractures are one of the most commonly encountered injuries of the craniofacial skeleton.²

The solid zygomatic bone acts as a part of the vertical and horizontal facial buttress, along with the malar eminence, which plays a key role in the determination of facial morphology. It forms a significant portion of the floor and lateral wall of the orbit thus it acts as one of the most common contributors to the orbital integrity.²

OZC fractures could lead to multiple ocular affections, such as diplopia, loss of vision, enophthalmos, or restricted eye movement, along with significant increase in the orbital volume owing to the

displacement of zygomatico-maxillary complex laterally along the vertical axis.^{3,4} Previous researchers have reported a good correlation between orbital volume increment and the degree of enophthalmos.^{3,5–9}

The main objective for the management of OZC fractures is the exploration and release of the herniated/entrapped soft tissue and restoration of the original orbital volume.⁵ Restoring the orbital volume may be conducted through reduction of the displaced bones or the use of implants for reconstruction and stabilization of the orbital walls.^{5–9}

Race, sex, and age are among other variables that affect the mean orbital volume, along with the utilized measuring technique. Regensburg et al. stated a 25.17 ± 0.06 cc average volume, while Devci et al. disclosed a mean volume of 28.41 cc.^{10,11}

The contemporary literature proposes manifold of techniques for orbital volume appraisal, with the consensus that availability, reproducibility, short learning curve, and short time to perform are the

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requirements of an ideal orbital volume measurement tool.^{11–14} Several studies employed the use of the Stereologic method based on the Cavalieri principle for the volumetric estimation using a Two-Dimensional (2D) hard copy image of the CT-Scan.^{11–14} Other studies utilized the summation of the consecutive cones areas obtained from axial or coronal CT-Scan slices using the standard computer-based programs.^{15–20} However, Kwon et al. reported an underestimate of the orbital volume by 6.9%–35.3% when utilizing the coronal cuts of the CT-Scan, where the variation in the orbit anterior limit was culpable for.¹⁵ The recent utilization of the Three Dimensional (3D) records and image analysis programs have ousted the difficulty in orbital geometry tracing and made orbital volume analysis much easier and consistent.^{8,9,21,22}

Since postoperative evaluation of OZC fractures is subjectively-based in most of the instances, quantitative orbital volume determination provides valuable data that acts as a patient-oriented parameter for the success of the utilized management when compared to the preoperative measurements or even with the contralateral side in cases of unilateral affection. Orbital volume evaluation is especially of value in rotational type fractures and when a reconstructive implant is used.^{5,16} Charteris et al. found a significant difference in the orbital volumes of surgically treated and non-surgically managed cases.¹² Numerous articles have highlighted the importance of orbital volume measurement of blowout fractures,^{7,13,15–18} where Ono et al. did their study on simple zygomatic fracture treated with Kirschner-wire, Özyazgan et al. and Sharma et al. utilized the stereological method and CT-Scan technique respectively for their orbital volume analysis.^{14,19,20} The literature falls short in the number of reports showing the preoperative and postoperative orbital volume changes following OZC fracture management.^{8,9}

This study was designed to determine the changes in the orbital volume of unilateral OZC fracture treated patients and compare it with their preoperative values and the control contralateral globe, using a 3D analysis software package. The specific aims were: 1) design and implement a retrospective study, 2) detect the percentage of decrease in the postoperative orbital volume when compared to the preoperative values, and 3) compare the postoperative values with the contralateral normal orbit and the pretreated values.

2. Materials and method

2.1. Study design

For the objective quantification of the accuracy of OZC fracture reduction, the investigators designed and implemented an analytical, single-observer, retrospective radiographic, chart review from all the patients admitted to the oral and maxillofacial surgery department for evaluation and management of a Orbitozygomatic Complex fracture between January 2017 and November 2018. The ethical clearance was granted from the Research Ethics Committee, Faculty of Dentistry, Alexandria University before undertaking the study.

To be included in this study, patients had to be 18 years or more with unilateral OZC fracture treated by ORIF under the same surgeon with adequate pre- and post-surgery helical 16-slice Computed Tomography (CT-Scan) records. In addition, surgical management was performed 2–7 days following patient admission, and a minimum postoperative follow-up of at least 3 months. Those records with patients with concomitant systemic diseases, patients with any previous history of fracture midface, patients with facial asymmetry, and records with obvious artefacts on CT-Scan images were excluded from this study.

2.2. Study variables

The primary outcome variable was the objective radiographic evaluation of the OZC fracture reduction accuracy by comparing the pre and postoperative orbital volumes. The DICOM files from the

preoperative and postoperative CT-Scans (Ingenuity Core; Philips Medical Systems, Cleveland, OH) were obtained in a high-resolution osseous window level setting and feed into a 3D segmentation and image analysis software (MIMICS 10.01, Materialise, Leuven, Belgium) in order to determine the orbital volume in cc.

The image was auto-traced at a Hounsfield threshold of 240 to 226 HU to create a soft tissues-contained mask within the orbital cavity. The orbital anterior boundary was set at the posterior lacrimal crest in the axial cross-section, while the posterior limit was the entrance point of the optical nerve into the orbit. The medial, lateral, superior and inferior boundaries were dictated by the bony structures of the orbit. To facilitate segmentation in areas of bony interruptions, areas of thin bone, and defective bony wall areas, a perpendicular straight line was drawn between the nearest bony stumps. Herniated tissue was not considered. Manual segmentation was initiated by setting a Region of Interest (ROI) in every CT scan coronal plane slice until the established orbital limits were reached, followed by grouping of these ROI to generate a 3D models of the manually segmented orbit. These 3D models were used to automatically calculate the orbital volume for the normal unaffected eye, the affected traumatized orbit, and the post-surgery orbit²¹ (Figs. 1 and 3). The postoperative volume in the fracture side was compared with the normal contralateral side and with the preoperative values using *t*-test (Figs. 2 and 4).

Inter-observer and intra-observer discrepancies due to the computer-based measurement method were calibrated in order to ensure a valid outcome for the orbital volume. Regarding the intra-observer reliability, each patient record was assessed twice by the same observer and changes in the reported volumes were analyzed with the Interclass Correlation Coefficient test (ICC). At the same time inter-observer reliability was ensured by taking ten random patient records to be assessed by another operator, and once again the interclass correlation coefficient test was used to determine the degree of agreement between the readings.¹⁰ Other variables were categorized into clinical demographic characteristics and type of approach used for the infraorbital rim fixation.

2.3. Statistical data analysis

All of the recorded data were documented, tabulated and statistically analyzed utilizing the IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Differences between groups were analyzed and the significance of the obtained results was set at the 5% level.

3. Results

While within the stated period of time the records documented a total of 73 patients surfed from OZC fracture, only 17 records were complete and fitted the inclusion criteria mandated by the study. The records revealed a male predilection (76.5%, $n = 13$), with a male to female ratio of 3.25:1 and an average age of 27.4 ± 3.8 years. Road Traffic Accidents (RTA) was the most prevalent etiological factor (47.1%, $n = 8$), followed by claimed falls (35.3%, $n = 6$) and Inter-Personal Violence (IPV) (17.6%, $n = 3$). Ten cases were on the right side and seven were in the left side (Table 1). All of the cases were managed with three-point fixation. The infraorbital rim for nine of the cases was approached through a transconjunctival incision, while the remaining cases were treated with transcutaneous ones.

The mean orbital volume of the unaffected side was 22.19 ± 0.36 cc, ranging from 21.55 to 22.73 cc. The preoperative orbital volume of the affected side ranged from 23.0 to 25.30 cc, with a mean value of 23.99 ± 0.66 cc, and a mean percentage of change from the contralateral normal orbit was +8.1%. The difference between the affected and the unaffected sides was statistically significant ($P < 0.001$) (Tables 2 and 3).

The mean postoperative orbital volume estimate of the affected side was 22.63 ± 1.03 cc, ranging from 19.83 to 24.75 cc. The

Fig. 1. Preoperative orbital volume analysis for a patient with left OZC fracture (Case 1). The volumetric analysis of the affected left eye revealing a value of 23.900 cc, while the control un-affected side value was 21.700 cc. The affected eye reported a percentage of increase of 110% from the control side.

postoperative values showed a statistically insignificant difference when compared to the control values of the unaffected side ($P = 0.333$) (Tables 2 and 3). The mean percentage of change reported in the postoperative affected orbit when compared to the normal orbit was $+2.0\%$. The treatment of the OZC fracture resulted in a mean of 1.354 ± 0.843 cc decrease when compared to the preoperative values with an average percentage of decrease of 6.1% . The difference between the pre and postoperative estimates of the affected side was statistically significant ($P < 0.001$) (Tables 2 and 3).

A high agreement was observed between the 2 measurements for the volume using the ICC test, indicating acceptable intra-operator reliability ($ICC = 0.97$). Furthermore, readings of the other observer

showed high agreement levels with those of the main observer, signifying acceptable inter-observer reliability ($ICC = 0.97$) (Table 4).

4. Discussion

The complex form and three-dimensional geometric architecture of the orbit makes the repair of OZC fractures a big challenge to maxillofacial surgeons, especially in cases burdened with orbital wall/s defects.¹⁶ The lack of information about an objective tool for the OZC fractures treatment modalities evaluation was the driving power for making this study as the majority of the studies are subjectively and anthropometrically oriented.⁴

Fig. 2. Postoperative volumetric analysis of case 1. The affected left side calculated a value of 23.200 cc, showing a decrease from the preoperative value by 3%.

Fig. 3. Preoperative orbital volume analysis for a patient with right OZC fracture (Case 2). The volumetric analysis of the affected right eye revealing a value of 23.130 cc, while the control un-affected left side value was 22.250 cc. The affected eye reported a percentage of increase of 104% from the control side.

Results of this study revealed that the normal unaffected orbit recorded a mean volume of 22.19 ± 0.36 cc across the 17 cases. The outcome in this supposedly control group was slightly higher than that stated by Oh et al., 21.39 ± 1.93 cc, and similar to that stated by Gribova et al., 22.47 ± 4.18 cc, both of which used a similar orbital volume measurement modality.^{8,21}

The affected fractured side showed a preoperative mean value of 23.99 ± 0.66 cc, which was much lower than that stated by Sharma et al. in both of their study groups, 25.5 ± 0.20 cc for group I and 25.6 ± 0.55 cc for group II, and comparable to that reported by Oh et al., 23.17 ± 2.0 cc.^{8,20} Difference may be attributed to the sample

size or demographic differences. In the current study, a statistical difference was found between the preoperative value and the contralateral unaffected normal globe volume ($P < 0.001$), as the affected orbit pretreatment values shows a mean percentage of increase of +8.1% from the control orbit. The post-traumatic increase in the orbital volume is self-explanatory and is usually accompanied by displacement of the retrobulbar fat and extraocular muscles in the region of the fracture, leading to enophthalmos.

The postsurgical volume of the affected side was 22.63 ± 1.03 cc, which although was higher than the contralateral side, 22.19 ± 0.36 cc, yet the difference was statistically insignificant

Fig. 4. Postoperative volumetric analysis of case 2. The affected right side calculated a value of 19.830 cc, showing a decrease from the preoperative value by 15% and a state of over-reduction.

Table 1
Unilateral OZC fracture patients charts demographic data.

		n
Age, years, mean $\pm$ SD	27.41 $\pm$ 3.78	
Gender (%)		
Male	76.5%	13
Female	23.5%	4
Fractured Side		
Right	58.8%	10
Left	41.2%	7
Trauma Etiology		
Fall	35.3%	6
Inter-personal Violence	17.6%	3
Road Traffic Accident	47.1%	8

SD, Standard Deviation

($P = 0.333$). A similar postoperative insignificant difference was stated by Sharma et al. and ono et al. ($P > 0.05$).^{19,20} Despite reporting a lower value than the normal side in their study, the difference stated by Oh et al. was once again insignificant.⁸ This wasn't the case with Özyazgan et al., as their study reported a significant difference between the surgically treated and the normal globe ($P < 0.05$).¹⁴ A statistically significant decrease in the postoperative orbital volume values when compared to the preoperative values were found ($P < 0.001$), with a mean decrease of 1.354 ± 0.843 cc. The percentage of change of the postoperative orbital values from the preoperative ones was -6.1% .

The mean percentage of increase in the postoperative orbit from the contralateral side was 2.0% , indicating the accuracy of treatment. Similar increase was stated by several authors as they came to the understatement that almost all postsurgical fractured orbits feature some extent of volume increase.^{7,14,20,23} Polder et al. stated that for the patient to perceive enophthalmos clinically, a 3 cc of orbital volume increase is required.^{13,18} None of the records in this study reported an increase from the contralateral normal eye that reaches the 3 cc threshold, hence the lack of patients subjective complain.

A consensus can be reached from the results of several authors about the lack of real significant intra-individual orbital volume difference between the right and the left orbits.^{7,14,20,23,24} Based on this agreement, this study employed the contralateral side as a control group to the affected orbit. Other studies pointed out a 7–8% of intra-individual volume inequality between the right and left orbits.²⁵ The 2.0% postoperative variation in this study was still within the stated intra-

Table 2
Unilateral OZC patients records and orbital volume estimates.

Pt. No	Age (Yr.)	Gender	Affected side	Cause	Normal Orbit volume (CC)	Affected Orbit volume (CC)		Difference CC (%)
						Preoperative	Postoperative	
1	23	Male	L	RTA	21.70	23.90	23.20	0.7 (3%)
2	34	Male	R	RTA	22.25	23.13	19.83	3.3 (15%)
3	31	Female	R	Fall	22.15	23.70	22.37	1.33 (6%)
4	26	Male	R	RTA	21.55	24.65	22.63	2.02 (9%)
5	24	Male	R	IPV	22.10	23.65	22.80	0.85 (4%)
6	32	Male	R	RTA	22.03	24.01	23.13	0.88 (4%)
7	24	Male	L	Fall	21.81	23.55	22.25	1.3 (6%)
8	28	Female	L	Fall	22.50	25.20	24.10	1.1 (5%)
9	35	Male	R	Fall	21.83	24.00	22.49	1.51 (7%)
10	26	Male	R	RTA	22.30	23.85	22.95	0.9 (4%)
11	24	Female	L	IPV	22.20	24.00	22.65	1.35 (6%)
12	25	Male	L	Fall	22.70	24.05	22.02	2.03 (9%)
13	26	Male	L	Fall	22.60	23.28	22.83	0.45 (2%)
14	28	Male	R	IPV	22.40	23.75	22.85	0.9 (4%)
15	23	Male	L	RTA	22.73	24.78	21.6	3.18 (14%)
16	27	Female	R	RTA	21.89	23.00	22.33	0.67 (3%)
17	30	Male	R	RTA	22.54	25.30	24.75	0.55 (2%)
Mean $\pm$ SD					22.19 $\pm$ 0.36	23.99 $\pm$ 0.66	22.63 $\pm$ 1.03	1.354 $\pm$ 0.843 (6.1%)

SD, Standard deviation; RTA, Road Traffic Accident; IPV, Inter-Personal Violence; L, Left side; R, Right Side.

Table 3
Orbital volume comparison between pre and postoperative affected and unaffected orbits.

		P-value
Normal Orbit	Preoperative affected Orbit	$< 0.001^*$
Normal Orbit	Postoperative affected Orbit	0.333
Preoperative affected Orbit	Postoperative affected Orbit	0.001^*

Significance between groups was done using Post Hoc Test (Bonferroni) for ANOVA with repeated measures.

*: Statistically significant at $p \leq 0.05$.

Table 4
Interclass Correlation Coefficient (ICC) of the measurements made by the main observer and the other observer.

	Interclass Correlation Coefficient
Intra-observer Reliability	0.97
Inter-observer Reliability	0.95

ICC outcome values: 0 = no agreement; 1 = perfect agreement.

individual difference hiatus, which further explain the reported insignificant difference.

The recent emergence of several 3D image analysis programs has made orbital volume analysis much easier and consistent with minimal window of error and variability all while providing a feasible solution to the errors of the outmoded modalities. Furthermore, these 3D reconstruction programs can process any heap of images regardless of the image scanner type. The 3D tracing feature further give the observer to reconstruct a defect-free virtual model of the orbit, making the volumetric measurement easier and more dependent.^{8,9,21,22} Roça et al. in order to prove the validity of the 3D image analysis programs exploited the tomographic method in order to 3D-print a prototype of the orbit, which was filled with saline in order to get the volume in cubic centimeters, and their results showed great validity and reliability for the utilized 3D software.²⁴ Furthermore, any orbital volume analysis modalities must possess several traits as worldwide availability, ease of performance and a short learning curve, utilization of the input of any radiological scan with certain standardization values, and the ability to be performed in a short amount of time, with low systemic measurement errors.¹⁴

The availability of postoperative CT-Scan gives the surgeon an

immediate clue and confirmation about the success of the utilized treatment modality, along with the patient's subjective acceptance and symptoms, however the evaluation of the orbital volume after the management of OZC fracture add a new frontier to objectively determine the reliability of the treatment, and could be used in the future for the comparison between different treatment modalities, devices and approaches. The call for a comprehensive study to objectively compare between prefabricated and customized fixation devices bearing in mind all of the variables is of a paramount importance.

This uni-centre study avoided the race from being a confounding factor and altering the results. Furthermore, every attempts were taken to ensure that the results were free of either intra-operator or inter-operator errors, and both discrepancies were reported to be within acceptable limits. This shows the reliability and repeatability of the utilized method by this study, and puts further validity to its ability to provide a quantitative unbiased appraisal of the orbital volumetric changes. The high inter and intra observer accordance of the results of this retrospective analysis has shown that orbital volume analysis can be safely used in the quantitative evaluation of the success of the OZC fracture management.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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