Original Article

USE OF MULTIDIMENSIONAL CT SCAN TO ASSESS STATUS OF ORBITAL VOLUME IN ZYGOMATICOMAXILLARY COMPLEX FRACTURES

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ABSTRACT

Background and objective: The zygoma has an intimate association with the orbit and therefore ZMC fractures are almost always associated with fractures of the internal orbit. The aim of the study was to assess the orbital volume changes and evaluate the post surgical outcome in zygoma fracture patients using CT scan

Methodology: A total of 24 patients with ZMC fractures were included in the study who underwent a CT scan preoperatively. The volumes of the traumatised and normal orbits were calculated for every patient and the difference was noted as orbital volume change. The amount of enophthalmos was measured by calculating the distance between the corneal and orbital apices on the injured side and was compared with that of the uninjured side. The relationship between clinical enophthalmos and orbital volume was assessed. Postoperatively after 6 months, the patients were subjected to a second CT scan to assess for the reestablishment of globe positions and orbital volumes.

Results: An increase in the orbital volumes in the preoperative phase with a mean percentage change of 9.70 ± 3.36 cm³ was noted. The P value of mean volume difference between the affected and control orbits was significant. The orbital volumes which showed a significant increase were reestablished in the postoperative period. However, no corelation could be demonstrated between the orbital volume change and the amount of enophthalmos.

Conclusion: Our study concludes that ZMC fractures increase orbital volumes on the affected side which can be restored by appropriate surgical means.

Key Words: zygomaticomaxillary; orbital volume; enophthalmos; computed tomography

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BACKGROUND:

Craniomaxillofacial trauma affects a significant proportion of injured patients. Zygomaticomaxillary (ZMC) fractures are common facial injuries which represent either the most common facial or the second in frequency after nasal fractures accounting for approximately 15- 23.5% of the maxillofacial fractures. [1]

Its high incidence probably relates to its prominent position within the facial skeleton frequently exposing it to traumatic forces. The zygoma is a pyramidal bone with a robust body and composed of four articulations commonly referred to as zygomaticomaxillary, frontozygomatic, zygomaticotemporal and sphenozygomatic sutures. [2,3] Injuries to the middle third of the face commonly destroy the integrity of the orbital skeleton and are frequently complicated by injury to the eye ranging between 2.7% and 90.6% in reported series. [4]

The volume of the orbit is the space created by the size and position of the orbital walls. Trauma influences a change in the intraorbital volume by causing inward and outward movement of a wall or part of a wall. [5] Enophthalmos, the recession of the globe into the bony orbit is a well known sequel to orbital trauma and is proposed to be caused by a reduction in balance of orbital contents and orbital volume. [6,7] It was thought to be secondary to orbital floor fractures alone but computed tomographic studies have shown that disruption of any of the walls or any type of complex pattern of facial fracture can produce this deformity. When associated with a displaced zygomatic fracture, early treatment consists of identification of the areas, reestablishment of position and fixation of the fractured segments. [6]

Diagnosis and treatment of orbital injury remain one of the most challenging areas in facial trauma wherein misdiagnosis along with inadequate repair can result in functional loss and severe cosmetic deformity. [8] The decision to reconstruct the orbital floor depends on the severity of structural disruption as well as clinically identified specific findings. Orbital volume measurement provides valuable data and by doing so we will be able to estimate the severity of the injury. Comparison of the orbital

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volume of the injured side with that of the uninjured one stands to be an accurate way of working out an evaluation.

CT being an established diagnostic modality is considered in the decision to proceed with orbital exploration so as to avoid complications such as enophthalmos as it demonstrates detailed osseous structures thus helping us to distinguish impact energy level based on segmentation and displacement. [8,9] This study used CT to investigate the relationship between changes in the orbital volume and decision for operative exploration of the orbital cavity as an aid to formulate a reconstructive plan.

MATERIAL AND METHOD

A prospective study with 24 patients diagnosed with only ZMC fractures from November 2018 to March 2020 was conducted in the department of Oral and Maxillofacial Surgery, Bapuji Dental college, Davangere and was approved by the Institutional Review Board of the hospital. Patients were informed about the study and a written informed consent was obtained. Patients were examined for the ZMC fracture clinically and for enophthalmos. Figure 1 a demonstrates a profile view and figure 1 b demonstrates the worm's view of a patient with right zygomaticomaxillary fracture.

Figure 1a: Pre operative front profile of patient with a right zygomaticomaxillary fracture

Figure 1b: Preoperative worm's view of the patient

CT EVALUATION OF ORBITAL VOLUME AND ENOPHTHALMOS

Bilateral orbital volumes were obtained from axial CT slices with the help of Toshiba Activion 16 slice CT machine. CT examinations were acquired with the following parameters: 100mA and 120kVp. Three dimensional reformations were constructed from the axial images.The slices in all the patients covered the area from the maxillary sinuses to the supraorbital rim. The radiological boundaries of the orbit were defined anteriorly by a plane connecting the anterior surface of the zygomaticofrontal process to the nasomaxillary suture and posteriorly by the optic foramen. [8]

1-5 mm slices were obtained from the CT image. Volume of the bony orbit were calculated by summing up the areas for all the relevant slices and multiplying them by the slice thickness (1-5mm) using the software Osirix. [10,11]

Figure 2 demonstrates calculation of the areas of affected and intact orbits in one slice. The volume of the traumatised orbit was compared with the volume of the intact orbit on the contralateral side in each patient.[8,12] The difference between the two orbits, healthy and injured, was defined as orbital volume change. However, a normal volume difference of 7-10% exists between the two orbits in any healthy individual. [5]

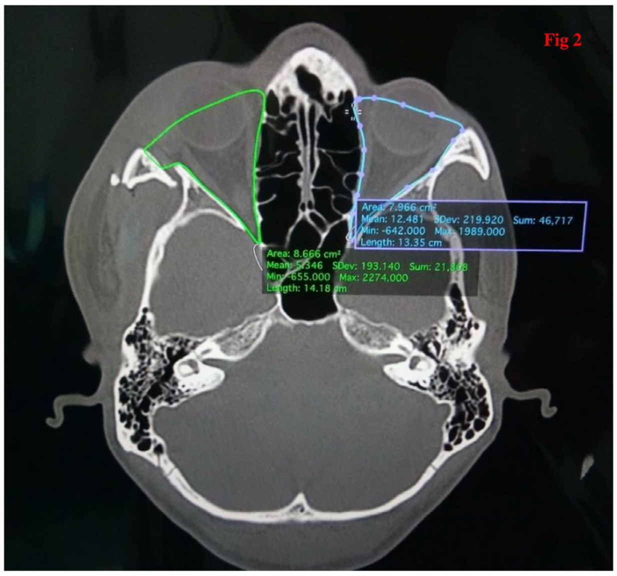

Figure 2: Calculation of areas of affected and control orbits in a single slice in axial section. Area in green- affected orbit; area in blue: control orbit

The amount of enophthalmos in this study was determined in the axial plane of CT scan by calculating the distance between the corneal apex and orbital apex in the injured side, and comparing this with the uninjured side [12,13] (figure 3). The relationship between the orbital volume and clinical enophthalmos was assessed.

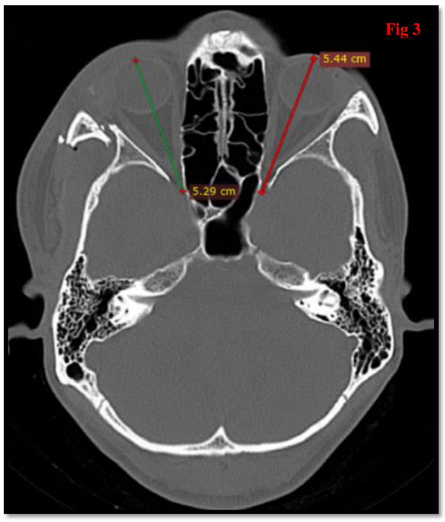

Figure 3: Pre operative linear measurement of enophthalmos in axial section of a CT scan

The patients were managed by surgical means in the early post-injury period.

After a period of 6 months the postoperative scans were obtained and the volumes of both the orbits along with the degree of enophthalmos were calculated once again to observe whether the volume lost/gained before trauma management has been restored or not. [8] (figure 4)

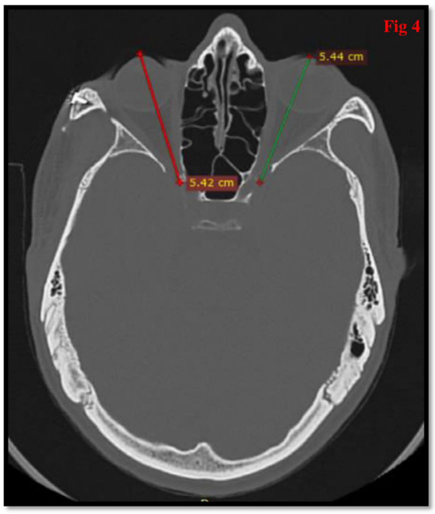

Figure 4: Post operative linear measurement of enophthalmos in axial section of a CT scan. Figure shows restoration of globe position.

RESULT :

A total of 24 patients were enrolled in the study out of which 23 (95.8 %) were male and 1 (4.2 %) was female. The age distribution was 15-55 years. There were 7 (29.1%) patients under the age group 15-25 years, 10 (41.6%) patients under the age group 26-35 years, 5 (21%) patients under the age 36-45 years and 2 (8.3%) patients under the age 46-55 years. (TABLES 1 a and 1 b)

TABLE 1a: Distribution of study subjects according to gender (N=24)

Gender	N	%
Male	23	95.8
Female	1	4.2

TABLE 1b: Distribution of study subjects according to age groups (N=24)

Age group	Sex		Total
	Male	Female	
15-25	7 (30.4%)	0 (0)	7
26-35	9 (39.1%)	1 (100%)	10
36-45	5 (21.7%)	0 (0)	5
46-55	2 (8.6%)	0 (0)	2
Total	23 (100%)	1 (100%)	24

Road traffic accidents were the main cause of fractures accounting for 63% (15 patients), second most common cause was fall (29%) with 7 patients and assault comprised of 2 patients (8%). The association between the type of trauma and preoperative volume percentage was not significant. (TABLE 2)

TABLE 2: Distribution of study subjects according to etiology of trauma and association with pre- operative volume percentage change (N=24)

Etiology	No of such cases	Mean volume %	SD	F	P value
RTA	15	9.626	3.803		
Fall	7	9.657	2.991	0.04	0.95
Assault	2	10.40	1.697		

One way ANOVA test, P value not significant

The mean volume of the control orbits in the patients was 24.97 ± 1.97 cm³. In the preoperative phase, the results showed an increase in the orbital volumes in all the patients. The mean volume of the affected orbits was reported to be 27.35 ± 2.01 cm³. The preoperative volume increase ranged from 1.1 to 3.9 cm³ (mean 2.41 ± 0.77 cm³) compared to the intact orbit. The mean percentage change in the volumes was 9.70 ± 3.36 %. (TABLE 3) The difference between the intact and the traumatised orbit was statistically significant. (TABLE 4)

In the postoperative phase, the mean volume of the affected orbits was reported to be 26.12 ± 1.73 cm³. The mean difference between the control and the affected orbits was 1.15 ± 0.56 cm³ following surgical management. The mean percentage change in this phase was 4.68 ± 2.47 %. (TABLE 3). The difference between the intact and the traumatised orbit was also statistically significant. (TABLE 4)

TABLE 3: Distribution of patients according to the volumes, volume differences and percentage changes in the volumes of orbits in preoperative and postoperative phases (N=24)

Variable	Mean	SD
Control (cm³)	24.97	1.97
Volume in PRE-OP Affected (cm³)	27.35	2.01
Volume in POST OP Affected (cm³)	26.12	1.73
Difference in PRE-OP volume (cm³)	2.41	0.77
Difference in POST-OP volume (cm³)	1.15	0.56
% Change in PRE-OP Volume	9.70	3.36
% Change in POST-OP Volume	4.68	2.47

TABLE 4: Comparison of volume between the affected and the unaffected sides in the pre-op and post-op periods

Variable	Side	Mean	Std. Deviation	P value
Preoperative	Unaffected side	24.97	1.97	0.001
	Affected side	27.35	2.01	
Postoperative	Unaffected side	24.97	1.97	0.036
	Affected side	26.12	1.73	

Paired t- test, P value significant

In the preoperative period, the mean volume difference between the traumatised and intact orbits was 2.46 ± 0.37 cm³ in patients who had significant radiographic enophthalmos whereas it was 2.40 ± 0.81 cm³ in those patients who did not show radiographic enophthalmos. The difference between these two groups was not significant (TABLE 5).

In the postoperative period, the mean volume difference between the traumatised and intact orbits was 1.10 ± 0.36 cm³ in patients who had significant radiographic enophthalmos before the surgery whereas it was 1.16 ± 0.58 cm³ in those patients who did not show enophthalmos in the imaging study. The difference between these two groups was not significant (TABLE 5).

The correlation between the mean volume changes and radiographic enophthalmos was calculated in the preoperative and post operative periods using linear regression method. The relation was not found to be statistically significant (TABLE 6).

TABLE 5: Comparison of mean volume difference in patients with CT evident enophthalmos vs patients with no enophthalmos

	r	Strength of correlation	P
Preoperative orbital volume difference vs enophthalmus	0.045	Positive and very weak	0.80
Post-operative orbital volume difference vs enophthalmus	-0.030	Negative and very weak	0.88

Pearson's correlation coefficient, P value not significant

TABLE 6: Correlation between mean volume changes and radiographic enophthalmos

Variable	CT evident enophthalmos	Mean	SD	P value
Pre-op	Enophthalmic side	2.4667	.37859	0.89
	Normal	2.4000	.81670	
Post-op	Enophthalmic side	1.1000	.36056	0.86
	Normal	1.1619	.58521	

Paired t test, P value not significant

DISCUSSION

The zygomaticomaxillary complex functions as a buttress for the face and is referred to as the cornerstone of a person's aesthetic appearance by providing prominence to the cheek and setting the midfacial width. The zygoma plays an integral role with the orbit as it reinforces the orbit and forms the majority of the lateral orbital wall and floor. [13] It is necessary to differentiate the fractures that affect these structures into two types that is orbitozygomatic and zygomatic.

This type of trauma may result in a downward sagging of the orbital contents into the sinus or may be associated with a separation at the fronto-zygomatic junction which if left untreated may develop enophthalmos. Such fractures should be distinguished from blowout fractures which can be in a pure form where there is splintering of the thin areas of the floor or medial wall but with an intact orbital rim. Impure blowout fractures cause fragmentation of the rim and its backward displacement leading to comminution of the orbital floor. [2,14]

In our study, only classical unilateral ZMC fracture cases with a history of recent trauma (upto 72 hours) have been included. It is generally accepted that the most common cause of orbital enlargement is not a blow-out fracture but an inadequately reduced zygoma fracture. When external rotation of the lateral orbital wall occurs it results in an increased intraorbital volume therefore, accurate reduction and rigid internal fixation of the zygoma should be the initial procedure in restoring the orbital volume. [8]

However, in blow-out fractures, studies have shown that the most important objective is to determine the post-traumatic orbital volume enlargement in order to avoid enophthalmos.

Defects in the anterior segment of the orbit do not cause significant changes in the volume of orbital cavity and therefore do not alter the degree of ocular projection except those in the anterior floor that entraps the inferior rectus and inferior oblique muscles that retract the globe leading to enophthalmos. Posterior floor and medial wall fractures have significant influence on the volume expansion and result in secondary enophthalmos. [6,8]

Orbital volume can vary up to 7.5 % between orbits in the same person and up to 22% between subjects. [5] In our study, the orbital volume on the affected side following trauma have shown an increase with difference varying from 1.2 cm^3 to 3.9 cm^3. This result is similar to those of previous studies. However, the volume percentage change ranging from 4.3% to 7.4% between the two orbits were not considered to be significant.

Post traumatic enophthalmos follows a composite injury to bone, ligaments and fat. It has been attributed to several theories such as an enlargement of the bony orbit, loss of ligament support, post traumatic fat/ atrophy, fat displacement, scar contracture and to the action of gravity on the orbital contents in an enlarged bony cavity. [7]

We have considered changes in the bony orbital volume as a parameter instead of calculating the soft tissue loss or fat necrosis in our study and comparing it to changes in enophthalmos as analysis of previous studies did not demonstrate statistically significant alterations of soft tissue volume, fat volume, neuromuscular tissue volume or globe volume. [11]

The use of Hertel exophthalmometer for measurement of enophthalmos has been objected as it shows low reliability and a poor repeatability in serial measurements. Measurements with Hertel can be misleading due to presence of soft tissue oedema in the acute period and require an intact lateral orbital rim for fixation, which in laterally displaced zygomatic fractures gets altered.

On the other hand computerised tomography helps to achieve more accurate values and has been recommended for preoperative evaluation of orbital trauma as a standard diagnostic technique. The CT scan machine could be connected to 3 dimensional software like Osirix or Radiant DiCom which could be helpful in analysing such measurements. Therefore all the patients in this study were evaluated for enophthalmos clinically by inspection and radiographically by measuring the distance between the apex of the orbit and the corneal apex. [15]

Cases that are routinely referred to ophthalmologists are the ones that include eyelid and conjunctival laceration, traumatic pupillary changes, failure of accommodation, reduction of visual acuity and choroidal tear. The patients in our analysis in comparison did not present with such defects or with any traumatic ophthalmoplegia, though they comprised of chemosis, subconjunctival hemorrhage, corneal abrasion and enophthalmos.[16] Nevertheless, detailed ophthalmic examinations were carried out in all the patients so that loss of vison should not be attributed to the surgical intervention and an appropriate sequence of management can be organised.

We restored the orbital volume in all the patients by appropriate reduction of the zygomaticomaxillary complex but a few patients required an orbital floor exploration and fixation of the orbital rim. For fixing the ZMC, the buttress was approached using the Keen's approach and the FZ region using the lateral eyebrow approach after which miniplates were placed. The orbital floor was explored via the infraorbital incision in selected patients and any evident fracture was reduced and fixated.

The decision to reconstruct the floor depends on the severity of structural disruption and specific associated clinical findings. Certain criteria that have been established in the past for deciding as to which patients need orbital rim and floor exploration are as follows: persistent diplopia throughout 7 days or more with perimuscular tissue entrapment, clinically significant enophthalmos of more than 23-mm with abnormal radiologic findings, radiographic evidence of severe displacement or comminution of greater than 50% of floor or herniation of soft tissue into the sinus, combined medial wall and floor fracture with soft tissue displacement, comminution or severe displacement of orbital rim, severe comminution or linear fracture of the zygoma and an evidence of a blow-in fracture. [17]

In our study not all patients who demonstrated a volume increase more than 10% were subjected to orbital floor exploration and rim fixation.

The decision was not only based on the degree of volume change but other factors such as the presence and severity of destruction of the floor, the rim and the zygoma itself were taken into consideration.

None of the patients in our study required reconstruction of the orbital floor. After a period of 6 months, on calculating the orbital volumes on the affected side from the CT scans, it was observed that the volumes have either been restored or the values were close to that of their counterpart. It should be noted that in certain instances a floor defect is generally not present before a ZMC is reduced but becomes apparent after its reduction.

For Guardian's evaluation, we can justify that the unsatisfied percentage at 1-month post-operative was due to the presence of residual suture materials fresh marks, and non-blinded edges yet, the scar is still immature. Regarding the disappointed patient guardian, we justify that this particular participant was having a psychosocial issue and was hardly uncooperative.

Esthetic problems arise when an enophthalmos of 2-3 mm or more is present. [12] Only three of our patients demonstrated a radiologically measured value of more than 2 mm out of which only one had clinically evident enophthalmos. This discrepancy results due to the soft tissue oedema in the immediate post trauma phase masking the enophthalmos. Cadaver specimen studies in the past exhibited that for each 0.5 ml of volume added to the orbit, globe position changes by 1 mm and a 3 mm displacement of medial and inferior walls results in volume change of 7.1 % and 11.8 % respectively. [5]

Therefore an orbital volume increase of 10% that would cause clinically significant enophthalmos was estimated to be an indication for surgery. However, one of the earlier studies stated that a volume increase or decrease by 20% is a reasonable criterion for exploring the orbital floor as well as fixing of the ZMC fractures. [9]

The increased percentage change from 10% to 20% indicates a definite fracture of one or more of the orbital walls which would cause drastic functional and aesthetic deformities in the late post-operative period hence mandating internal orbit reconstruction.

Considering the correlation between the orbital volume and enophthalmos, several studies have demonstrated positive interrelationship where for enophthalmos ranging from 0.4 mm to 1 mm there is 1 cm^3 increase in volume. [12] Our study could not assess such a linear association and that patients had no clinically or radiologically evident enophthalmos even on having upto 3.9 cm^3 of volume difference which could be due to the relatively small amount of sample size or the inclusion of classical ZMC fractures that did not significantly affect the integrity of the orbital walls. Also in the acute trauma period the CT scans were obtained immediately so post traumatic swelling and oedema could give an inaccurate measurement of enophthalmos.

We discerned that all the patients in the postoperative period were satisfied with the treatment that was given to them. Hence our results revealed that following a ZMC fracture there is an increase in the orbital volume which has been shown to be reestablished by surgical means. However, the criterion of more than 10% of volume change may be too stringent to warrant a surgical exploration of the floor and should depend upon other clinical and radiological parameters. No correlation could be stated between the volume changes and enophthalmos. The drawbacks of our study were that firstly calculation of the volumes by summing up the areas of the individual slices was a time consuming process and secondly there exists a possibility of high chances of human error. Softwares which could measure the volume directly or a cone beam computed tomography might be preferred in such cases to fasten the process.

CONCLUSION

In conclusion, the data of our study suggests that in ZMC fracture patients do have an increase in orbital volume which can be evaluated. CT scan might be the diagnostic test of choice in orbital trauma patients both to assess orbital volume changes post trauma as well as to evaluate the restoration of the gained or lost orbital volume post surgical. However, measuring the orbital volume by the described method in this study might be time-consuming with high chances of errors. The results of this study could not find a correlation between the orbital volume changes with enophthalmos indicating a need for a larger patient population and that classical ZMC fractures might not significantly affect the integrity of orbital walls.

CONFLICT OF INTEREST

The authors have no competing interests to declare that are relevant to the content of this article

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