ORBITAL DEFECT RECONSTRUCTION: THE USE OF PREFORMED TITANIUM PLATES VERSUS CUSTOM-MADE TITANIUM COMPUTER ASSISTED IMPLANTS.

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ABSTRACT

Purpose: The aim of this study was to compare the use of prefabricated titanium implants versus custom-made computerized assisted plate in the reconstruction of the internal orbital defects. Patients and methods: Eighteen trauma patients suffering from primary internal orbital defects were included in this study between 2013 until 2015 at Al Zahraa University Hospital, Cairo, Egypt. The study subjects presented with a variety of functional and esthetic deficits which indicate surgical correction. They were divided into two equal groups, 9 for each. Clinical and radiographic parameters analyzed statistically. Results: both techniques; succeeded in reducing orbital volume and increasing globe projection in the affected eye. There was a non-significant difference between the studied groups in the degree of accuracy of volume correction and in the correlated correction of corneal projection despite of the great degree of preoperative orbital volume distortion in both groups. There was no statistically significant difference between both groups, in the accuracy of correction of the degree of hypoglobus, palpebral fissure width narrowing, reduction of visual acuity, diplopia and motility restriction. Conclusion: The use of preformed implants for orbital floor and medial wall reconstruction saves time and renders traumatic intraoperative bending and adjustment of the implants unneeded, which is of particular importance in cases of poly trauma. However, non-statistically significant differences were found between it and the custom individually computer assisted implants so it is probably not necessary for routine use in small orbital blowout fractures but will be preferred in bilateral cases, mal union, complex orbital injuries and post ablative orbital defects.

Keywords: orbital defect reconstruction; preformed plate; custom-made plate.

INTRODUCTION

Trauma is a rolling pandemic, that emerges and blossoms in new forms. The orbit is involved now more than the past in the cases of craniofacial trauma with a variety of presentations: panfacial fractures, frontoorbitozygomatic, nasoorbitoethmoidal, orbito-zygomatic, orbitozygomaticomaxillary, internal orbit, and combination. [1,2]: orbital fracture may result in changes in the orbital dimensions that may lead to serious complications such as; diplopia, enophthalmos, visual acuity disturbances, restricted ocular motility and cosmetic problems. The unique anatomy of the orbit and the resulting surgical approaches make the process of fitting and implants alignments difficult, time consuming and operator dependent, especially if the deep orbital cone is affected or scarred. In the literature, there are many conflicting reports about classifications, surgical techniques, type of implant materials, and ideal time to perform surgery.[3–7] Recently, preoperative computer-assisted planning with construction of stereolithographic (STL) models offers highly accurate models of the bony orbit for preoperative evaluation, surgical
planning, teaching and can act as a template for custom prosthesis adjustment and/or manufacturing. These technologies increase the orbital surgeon’s options in management of the complex orbital defect, and lightened the way for more accurately reconstruction of the bony orbit and optimal treatment outcomes.[8–11]

The goals of treatment for complex orbital deformities include re-establishment of a structural framework; normalization of orbital volume; prevention of complications, such as enophthalmos, extraocular muscle restriction, and visual disturbances; and achievement or improvement of facial esthetics. The outcome of the surgical correction depends to a great extent on the shape of the orbital implants and their adequate placement.

The aim of this study was to compare the use of prefabricated titanium implants versus custom-made titanium implant in the reconstruction of the internal orbital defects.

**SUBJECTS AND METHODS**

**Study design and setting**

A prospective cohort study carried out on 18 trauma patients suffering from either primary internal orbital defects indicated for unilateral internal orbital reconstruction at Alzahraa University Hospital, Department of Oral and Maxillofacial Surgery, Cairo, Egypt. The study approved from the faculty ethical committee and the study performed according to the declaration rules of Helsinki. All patients signed informed consent before the operation.

This study compared the use of prefabricated titanium implant in the form of preformed orbital plate versus the computer-assisted custom-made titanium implant in the reconstruction of the internal orbital defects.

**Study sample**

Eighteen trauma patients suffering from primary internal orbital defects were included in this study. The study subjects presented with a variety of functional and esthetic deficits which indicate for surgical correction. They were divided into two equal groups, 9 for each. Nine patients received orbital medial wall and floor defect reconstruction procedure, using preformed orbital plates (Synthes Matrix MIDFACE Preformed Orbital Plates 0.3 mm profile) (Fig. 1). 9 patients received flat anatomical orbital plates bent, adjusted and fitted preoperatively on a computer assisted, custom made template (COMPLEX ORBITAL FLOOR PLATE 0.3 mm profile. The Stryker, Leibinger. UK Ltd) (Fig. 2)
Study variables
All patients received Pre and postoperative Hertel exophthalmometry, Volume measurement of preoperative fractured orbit, postoperative reconstructed orbit and unaffected orbit of the same patient. Patient Examination and Preoperative Preparation included: Full case history, Clinical examination & accurate facial and craniofacial evaluation, Focused ophthalmologic assessment of the eye, Radiographic evaluation, Standard laboratory investigations which included: Complete blood picture, fasting blood glucose level, liver enzymes level, creatinine blood level, coagulation profile, electrocardiogram and chest radiograph were ordered when indicated and Photographs taken with patient permission.

Surgical technique:
Under general anesthesia, the selection of the surgical approach in our study was based on the type and extent of the orbital injury and on the presence of associated midfacial fractures (Fig.3). The patients of the two groups were preoperatively and postoperatively evaluated clinically, ophthalmologically and radiographically at one, three and six months. The vertical ocular position (degree of hypoglobe) and the palpebral fissure width (the vertical inter fissure distance) were measured and evaluated clinically using a hand held ruler (Table 1, 2). Motility restriction was evaluated ophthalmologically by using the Hess screen test, binocular diplopia was also evaluated and the visual acuity was evaluated and recorded according to Snellen chart in decimal value (Table 3, 4). The corneal projection was assessed and measured by Hertel exophthalmometry device and by CT based Hertel examination also.

(Fig. 3) Showing, the reconstruction of the internal orbit in patients of group B by using the individually adjusted custom orbital plates. The plate bridged the defect and reconstructed the normal orbit anatomy configuration titanium screws in the orbital rim were used for fixation.

Data collection and technique
Preoperative, immediate and 6-month postoperative high resolution CT scan was performed for all patients. Where pre- and postoperative CT volumetric assessment was performed using specialized software for volume calculation of the intact, traumatized and reconstructed orbits. In group B, CT data was introduced to the surgical planning software program to obtain the virtual STL model which was transferred to a physical orbital model where the flat titanium plates were bent and adjusted onto the models preoperatively.

The calibers used to evaluate the accuracy of orbital fractures reconstruction included: CT calibers: all patients undergo Pre and postoperative Hertel exophthalmometry, Volume measurement of preoperative fractured orbit, postoperative reconstructed orbit and unaffected orbit of the same patient. Ophthalmologic calibers: all patients undergo Pre & post. 1, 3 & 6 months Hess screen chart for restricted motility evaluation, Pre & post. 1, 3 & 6 months
Hertel Exophthalmometry for enophthalmos measurement, Pre & post. 1, 3 & 6 months diplopia evaluation and Pre & post. 1, 3 & 6 months visual acuity evaluation.

Clinical calibers included: Ocular position and Palpebral fissure shape and size.

The presence of enophthalmos was defined in this study as retrusion of the globe more than 2 mm relative to the opposite side. The degree of enophthalmos was assessed by two methods the first which is based on CT, has a disadvantage that the enophthalmos evaluation was limited to the CT interval only, which was at preoperative, immediate and 6 months postoperative.

While the other method used the Hertel exophthalmometer device, which measures the difference between the anterior corneal surface and the lateral orbital rim, this method was available in every ophthalmological examination time; it allowed serial readings over time. The study is beneficial for evaluating the change in corneal projection by Hertel device many times at preoperative and postoperative stages. The documented readings for comparison were after resolution of edema at 1, 3 & 6 months postoperatively (Table 5, 6).

**Statistical analysis**

Data was collected and analyzed by Microsoft excel and Statistical Package for Social Science (SPSS) version 16. Descriptive frequency data analysis was expressed as mean ± SD, and as number and percentages. Inferential result statistics for group comparison done using unpaired student’s t test. Determining the extent that a single observed series of proportions differs from a theoretical or expected distribution was done using the Chi square test. P value > 0.05 was considered non-significant.

**RESULTS**

Eighteen trauma patients suffering from primary internal orbital defects were included in this study. The study subjects presented with a variety of functional and esthetic deficits which indicate for surgical correction. They were divided into two equal groups, nine for each. The distribution of fracture pattern with orbital involvement in group A and B patients was the same and was diagnosed as 50% isolated blowout, 17% NOE type1 and 33% displaced ZMC. All the patients were operated within 7-10 days interval from trauma, with open reduction and internal fixation with orbital reconstruction.

Clinical and ophthalmological results showed that all of the patients of both groups; showed complete correction of the ocular dystopia, the affected side showed good esthetic outcomes compared with the intact sides after primary reconstruction. Correction of globe malposition as well as correction of the pupil's level were achieved in all patients (Table 1).

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
<th>Preoperative degree of hypoglobes in mm</th>
<th>Difference in level from intact eye 1-month post</th>
<th>Difference in level from intact eye 3-months post</th>
<th>Difference in level from intact eye 6-months post</th>
<th>Postoperative degree of correction in mm</th>
<th>Degree of correction %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Mean ± SD</td>
<td>4.67 ± 3.67</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>4.67 ± 3.67</td>
<td>100.00 ± 0.00</td>
</tr>
<tr>
<td>Range</td>
<td>0 – 10</td>
<td>0 – 0</td>
<td>0 – 0</td>
<td>0 – 0</td>
<td>0 – 10</td>
<td>100 – 100</td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>Mean ± SD</td>
<td>3.83 ± 2.40</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>3.83 ± 2.40</td>
<td>100.00 ± 0.00</td>
</tr>
<tr>
<td>Range</td>
<td>0 – 7</td>
<td>0 – 0</td>
<td>0 – 0</td>
<td>0 – 0</td>
<td>0 – 7</td>
<td>100 – 100</td>
<td></td>
</tr>
<tr>
<td>Group A Vs Group B</td>
<td>0.65 NS</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.65NS</td>
<td></td>
</tr>
</tbody>
</table>

Normal palpebral fissure width and shape were obtained in all cases except one patient in-group A, who exhibited mild degree of increased scleral show (table 2).
In the correlated correction of corneal projection despite of the great degree of preoperative difference between the studied groups in increasing globe projection in the affected eye (Fig.4), there was a non-significant difference between the studied groups in the degree of accuracy of volume correction and in the correlated correction of corneal projection despite of the great degree of preoperative orbital volume distortion in both groups (Table 5 and 6).

Table 2: The mean value of palpebral fissure width measurements in mm of both the intact and affected side preoperatively and at 1, 3& 6 months postoperatively.

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
<th>Intact side width (mm)</th>
<th>Preoperative affected side width (mm)</th>
<th>Preoperative degree of reduction in width (mm)</th>
<th>1- Month postoperative affected side width (mm)</th>
<th>3- Months postoperative affected side width (mm)</th>
<th>6- Months postoperative affected side width (mm)</th>
<th>Postoperative Degree of gained width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Mean ± SD</td>
<td>10.83 ± 1.33</td>
<td>8.67 ± 3.93</td>
<td>3.17 ± 1.83</td>
<td>11.67 ± 1.37</td>
<td>11.17 ± 1.33</td>
<td>11.17 ± 1.33</td>
<td>3.50 ± 3.35</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>9 - 12</td>
<td>5 - 15</td>
<td>0 - 5</td>
<td>9 - 13</td>
<td>9 - 12</td>
<td>9 - 12</td>
<td>0 – 7</td>
</tr>
<tr>
<td>Group B</td>
<td>Mean ± SD</td>
<td>10.00 ± 0.00</td>
<td>6.17 ± 3.76</td>
<td>3.83 ± 3.76</td>
<td>10.00 ± 0.00</td>
<td>10.00 ± 0.00</td>
<td>10.00 ± 0.00</td>
<td>3.83 ± 3.76</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>10 - 10</td>
<td>0 - 10</td>
<td>0 - 10</td>
<td>10 - 10</td>
<td>10 - 10</td>
<td>10 - 10</td>
<td>0 – 10</td>
</tr>
<tr>
<td>Group A Vs Group B</td>
<td>0.19 NS</td>
<td>0.29 NS</td>
<td>0.71 NS</td>
<td>0.03 NS</td>
<td>0.08 NS</td>
<td>0.08 NS</td>
<td>0.86 NS</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: The preoperative and 1, 3& 6 months’ postoperative degree of motility limitation in the traumatized side eye.

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
<th>Preoperative affected side means of ocular motility limitation</th>
<th>1- Month postoperative degree of limitation</th>
<th>3- Months postoperative degree of limitation</th>
<th>6- Months postoperative degree of limitation</th>
<th>Correction percent %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Mean ± SD</td>
<td>2.17 ± 2.23</td>
<td>0.50 ± 1.22</td>
<td>0.33 ± 0.82</td>
<td>0.17 ± 0.41</td>
<td>95.83 ± 8.33</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0 – 6</td>
<td>0 - 3</td>
<td>0 - 2</td>
<td>0 - 1</td>
<td>83 – 100</td>
</tr>
<tr>
<td>Group B</td>
<td>Mean ± SD</td>
<td>4.33 ± 4.63</td>
<td>0.67 ± 1.63</td>
<td>0.33 ± 0.82</td>
<td>0.00 ± 0.00</td>
<td>100.00 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0 – 12</td>
<td>0 - 4</td>
<td>0 - 2</td>
<td>0 - 0</td>
<td>100 – 100</td>
</tr>
<tr>
<td>Group A Vs Group B</td>
<td>0.34 NS</td>
<td>0.85 NS</td>
<td>1.00 NS</td>
<td>0.36 NS</td>
<td>0.39 NS</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: The preoperative and 1, 3& 6 months’ postoperative mean of the visual acuity of both sides in the three groups of patients.

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Mean ± SD</td>
<td>0.78 ± 0.25</td>
<td>0.61 ± 0.61</td>
<td>0.78 ± 0.25</td>
<td>0.78 ± 0.25</td>
<td>0.65 ± 0.30</td>
<td>0.74 ± 0.32</td>
<td>0.74 ± 0.32</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0.5 - 1</td>
<td>0.01 - 1</td>
<td>0.5 - 1</td>
<td>0.5 - 1</td>
<td>0.25 - 1</td>
<td>0.25 - 1</td>
<td>0.25 - 1</td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>Mean ± SD</td>
<td>0.82 ± 0.31</td>
<td>0.83 ± 0.29</td>
<td>0.82 ± 0.31</td>
<td>0.82 ± 0.31</td>
<td>0.83 ± 0.29</td>
<td>0.83 ± 0.29</td>
<td>0.83 ± 0.29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0.25 - 1</td>
<td>0.3 - 1</td>
<td>0.25 - 1</td>
<td>0.25 - 1</td>
<td>0.3 - 1</td>
<td>0.3 - 1</td>
<td>0.3 - 1</td>
<td></td>
</tr>
<tr>
<td>Group A Vs Group B</td>
<td>0.80 NS</td>
<td>0.29 NS</td>
<td>0.46 NS</td>
<td>0.46 NS</td>
<td>0.33 NS</td>
<td>0.61 NS</td>
<td>0.61 NS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Radiographic results of this study demonstrated that both techniques that were used in orbital reconstruction were reliable in restoring orbital volume and globe projection in the traumatic orbits. Where both techniques; succeeded in reducing orbital volume and increasing globe projection in the affected eye (Fig.4). There was a non-significant difference between the studied groups in the degree of accuracy of volume correction and in the correlated correction of corneal projection despite of the great degree of preoperative orbital volume distortion in both groups (Table 5 and 6).
(Fig. 4) Shows: The preoperative and postoperative CT scan of case no 6A. The preoperative coronal section demonstrates the Rt side orbital fractures of both floor and medial wall with herniated orbital content in both maxillary and ethmoidal air sinuses (a). The postoperative coronal section demonstrates the restoration of the orbital contour by the POP (b). Preoperative axial cut demonstrates a defect that involves the entire medial wall (c). The postoperative axial CT scan demonstrates the adequate extension of the medial part of the plate and restoration of the postero-medial defect (d). A preoperative sagittal cut shows the complete loss of the floor (e). Postoperative sagittal CT scan demonstrates the restoration of the normal ascending slope of the posterior orbital floor and the adequate restoration of the height of the posterior orbit by the plate (f) with comparison to the left normal side (g).

All patients recovered successfully and had full ocular movement postoperatively, except one patient in group A, who showed persistence of mild restriction in upward gaze. Complete elimination of diplopia was achieved in six patients and significant improvement of diplopia incidence was achieved in the other three. No reduction of the visual acuity after orbital reconstruction which indicates the safety and the proper augmentation of the three reconstruction techniques (Fig.5).
(Fig. 5) The preoperative and 6-months postoperative photos; showing the difference in clinical pictures of case no.1 in group A. The preoperative right eye with exophthalmos, increased scleral show, increased in vertical inter fissure distance and unequal pupils level (a). Postoperative appearance of the face with the significant improvement in globe projection, corrected level of pupils, normal shape and size of palpebral fissure when compared to the intact side (b). The worm view demonstrates the preoperative degree of right eye proptosis when compared to the intact side (c). Correction of the corneal projection as shown at-6 months postoperatively (d).

Table 5: the means of corneal projection reading, preoperatively of the intact and enophthalmic eye and postoperatively at 1, 3 & 6 months of the corrected eye.

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
<th>Preoperative unaffected side (mm)</th>
<th>Preoperative affected side (mm)</th>
<th>Affected side 1- month postoperatively (mm)</th>
<th>Affected side 3- months postoperatively (mm)</th>
<th>Affected side 6- months postoperatively (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>Mean ± SD</td>
<td>18.00 ± 1.67 15.33 ± 3.61</td>
<td>17.50 ± 3.35 17.50 ± 2.35</td>
<td>14 – 20</td>
<td>14 – 20</td>
<td>17.17 ± 2.48</td>
</tr>
<tr>
<td>Range</td>
<td>16 – 20 12 - 21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>Mean ± SD</td>
<td>17.00 ± 4.24 11.67 ± 4.03</td>
<td>17.67 ± 1.51 16.00 ± 4.65</td>
<td>16.00 ± 4.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>9 - 21 4 - 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group A Vs Group B</td>
<td>0.61 NS 0.13 NS</td>
<td>0.89 NS 0.50 NS</td>
<td>0.60 NS</td>
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</tr>
</tbody>
</table>
Table 6: the means and differences in orbital volume of both orbital sides preoperatively and postoperatively.

<table>
<thead>
<tr>
<th>Group</th>
<th>Value</th>
<th>Intact (control) side volume (cm³)</th>
<th>preoperative affected side volume (cm³)</th>
<th>postoperative reconstructed side volume (cm³)</th>
<th>Degree of distorted volume* (cm³)</th>
<th>Degree of reconstructed volume** (cm³)</th>
<th>Degree of uncorrected volume (cm³)</th>
<th>Percentage error (accuracy) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
<td>27.50 ± 1.87</td>
<td>27.97 ± 2.42</td>
<td>7.67 ± 2.47</td>
<td>1.17 ± 1.08</td>
<td>4.396 ± 4.159</td>
</tr>
<tr>
<td>Group A</td>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
<td>26.72 ± 1.82</td>
<td>27.63 ± 2.45</td>
<td>7.25 ± 2.52</td>
<td>1.18 ± 1.10</td>
<td>4.39 ± 4.00</td>
</tr>
<tr>
<td>Group B</td>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
<td>26.99 ± 8.64</td>
<td>27.58 ± 10.11</td>
<td>7.25 ± 2.52</td>
<td>1.18 ± 1.10</td>
<td>4.39 ± 4.00</td>
</tr>
</tbody>
</table>

Discussion

The reconstruction techniques used in this study proved to be reliable with a high degree of accuracy in reconstructing the preinjury 3-dimensional architecture of the orbital frame and internal orbit. And in establishing the orbital volume resulting in improvement of the clinical and ophthalmological outcome with respect to visual acuity, enophthalmos, ocular motility, diplopia, and esthetics. We included only unilateral cases only to ensure the availability of preoperative and postoperative comparison to the intact side.

The mean timing of surgery was 8.5 days (7 -10). The proponents of early intervention advocate that reconstructive surgery should be performed soon after injury to prevent enophthalmos and minimize progressive fibrosis and contraction of the prolapsed tissue[4,5,12,13].

In the present study the indication for surgical intervention was based on radiographic CT, ophthalmologic finding and clinical signs and symptoms. According to the literature[5,7,14,15] “major” orbital wall defects should be reconstructed as anatomically as possible; to avoid unpleasant and handicapping functional and cosmetic impairments. In the present study the surgical indications that were based on CT findings were: Severe defect involving more than 50% of floor or medial wall or both of them, herniated soft tissue in maxillary and/or ethmoidal sinus or tightly entrapped inferior rectus or medial rectus in trap door fracture, fracture of posterior cone or compression of a bone fragment on the optic nerve. Involvement of the floor and/or medial wall in impure blow out fractures eg. ZMC and NOE fractures; which are supported by the clinical signs of orbital involvement are also indications for surgery.

The clinical findings that dictated surgical intervention in this study were the same as other authors and included hypoesthesia along the infraorbital nerve distribution, narrowing of the palpebral fissure (a sign of medial wall fracture), hypoglobes, or globe dystopia, enophthalmos more than 3 mm [16–18], restriction in ocular motility[4,19–21], Soft tissue entrapment [22–24], unresolved diplopia in primary gaze. Narrowing of palpebral fissure was seen in patients with medial wall fracture. Many authors[22,25,26] reported that tightly entrapped medial rectus in the fracture site can demonstrate retraction of the palpebral fissure due to the force generated by the lateral rectus muscle tugging against the tightly entrapped medial rectus.

We used Hertel’s exophthalmometer for measuring enophthalmos in agreement with many studies[27,28] A technical problem which is considered as a
limitation or a disadvantage of exophthalmometry was that it relies on the lateral orbital rim; which may be displaced in some cases where in those cases enophthalmos is measured based on CT. The Hess screen test was used for diagnosing ocular motility disorders. In agreement with other studies [20,24,29] it was found that the test is simple, repeatable and reliable as it permits the interpretation of the results in a graph rather than in a strictly numerical fashion. Two of our patients had decreased visual acuity and color indiscrimination which are considered as a limitation in the Hess Screen test.

In the present study, the CT soft tissue window allowed the identification of orbital fat herniation, the entrapment of the extraocular muscles and whether the periorbita and fascial sling were disrupted or not. It allows visualization of the inferior fibrofatty tissue, which is less conspicuous than muscle in CT scans, however it plays a major role in both preoperative and postoperative ocular motility[23,30–33]. Bone window and software based CT scan were employed in the present study for assessing the severity of the fractured defect. Quantitative classifications of orbital defects were achieved, which helped in determination of the surgical indication as well as better prediction of the surgical technique and comparison of results. The use of CT calipers for bony evaluation of orbital fractures in this study are in agreement with other studies.[19,30,31,34]. The performed technique demonstrates the feasibility and predictability of measuring orbital volume which is in accordance with other studies.[5,35]. The computer-assisted techniques used in this study manipulated the CT data sets and used mirror imaging of the uninvolved side. This allowed an ideal virtual reconstruction of the internal orbital walls and generation of correct 3D stereolithographic models of the mirror imaged orbits. The accuracy of this technique was proved by many studies.[5,8,32] A limitation of this technique is that it assumes orbital/facial symmetry.

The titanium implant was selected in this study because of its ability to retain complex shapes so provides enough mechanical support to the internal orbital contents. The titanium implants are easily positioned, adaptable to the regional anatomy, easy to contour, easily inserted, delivered and manipulate, easily cut and sized in the operating room and is radiopaque [15,36].

Benefits of preformed orbital plates are that intraoperative bending and adjustment was not needed. This facilitated the precise and quick placement of the implants. Its insertion through transconjunctival approach was less time-consuming and less traumatic to the periorbital tissues. This study faced technical limitation of this plate in the complex orbital defects which extended lateral to the inferior orbital fissure this is because this 3D implant was designed to closely approximate the topographical anatomy of the human orbital floor and medial wall only. The plate exhibits lateral shortage in coverage of such defects which necessitates the use of additional titanium mesh to cover the missed part. In addition to that, another disadvantage of the plate was its high cost.

In this study the computer-assisted (CA) techniques used titanium plates bent and adjusted on custom made template, this techniques has many advantages including greater accuracy, shorter operation time, straightforward to plan and construct models and detection and avoidance of the highly vulnerable structures such as the
optic nerve. This technique is excellent for large wall defects. There is an agreement across the studies\[8,15,37\] that the preplanned position of the customized titanium plate yielded the preferred implant shape. While the disadvantage of this technique was the length of time required for building the model, the need to spend time cutting and shaping the implant before the operation. All patients showed near normal vertical eye position and the affected side showed good esthetic outcomes compared with the intact sides. There was a non-significant difference among the two groups in accuracy of dystopia correction. Patients of group B showed accurate correction of vertical palpebral fissure width in relation to the normal side. On the other hand group A showed an increase in the vertical palpebral interfissural width with scleral show of 0.83 ±1.33 mm in comparison to the intact side, this decreased to 0.33 ± 0.82 mm by the end of follow up by massage of the lower lid. This is attributed to the use of subciliary approach which is in agreement with the studies \[16,38\] .

Although the great degree of restriction in group B preoperatively; the two groups of patients successfully recovered full ocular movement postoperatively, except for one patient in group A who suffered from persistence of mild restriction in upward gaze, although the release of entrapment of herniated soft tissue this may be attributed to nerve damage or muscle hematoma and edema. Failure to restore the full ocular movement was reported\[4,5,24\] to be due to the incarceration and contracture of the inferior fibrofatty complex between bones fragments or due to tissue contusion or shearing or laceration that result in attenuated ischemia which may compound the insult.

The great degree of preoperative binocular diplopia was completely resolved postoperatively in 5 of 9 patients of group A and B. The other 4 patients showed a significant improvement of diplopia, but a residual diplopia persisted in extreme gaze. This could be attributed to the different factors that influence diplopia such as timing, type of fracture, degree of fracture, the severity of preoperative diplopia in primary gaze, damage to the extraocular muscle as fibrosis or coexistent neurogenic injury. The amount of residual diplopia in this study is consistent with many researches \[4, 23, 39\] that reported the incomplete improvement of diplopia after surgical correction.

In the 2 studied groups there was not any reduction in visual acuity in the immediate 1, 3 & 6 months postoperatively as opposed to the preoperative visual acuity, which indicates the safety of the two types of reconstruction techniques.

Comparing the reconstructed orbital volume of the affected side to the orbital volume of the intact side showed an increase in the restored volume by 1.17 ± 1.08 cm³ in group A, 1.18 ± 1.1 cm³ in group B. Despite the degree of preoperative distortion of volume which was significantly more in group B because of complexity of orbital fractures in that group; there was no statistical significant difference between the accuracy of the two techniques in restoring the orbital volume \(p > 0.05\). The increase in reconstructed volume may be attributed to inadequate implants augmentation of the most superior and posterior area of medial wall and/or inadequate reduction of the ZMC fracture. This degree of difference in volume in relation to the normal side is in accordance with that reported by Ye et al, \[39\] and Kwon et al \[33\], who reported 1.1% and 0.6% respectively. We used the volume of unaffected contralateral orbit as
control in accordance to other studies [40] that considered the normal side to be relatively acceptable control even though studies reported that there is a difference in normal volume between the two orbits about 8%.

The two techniques were reliable in restoring the degree of enophthalmos. There was a non-significant difference between the two studied groups in the corneal projection correction (P > 0.05). Postoperative enophthalmos was corrected with degree of reduction from the normal side 1.17 ± 1.17 mm in group A, 1.00 ± 0.89 mm in group B. The results of this study conform with results of other studies which found that a decrease of 1 cm³ in volume after reconstructive surgery resulted in a decrease in enophthalmos by 0.66 mm[39], and is consistent with previous reports on the high correlation between orbital volume increment and the degree of enophthalmos which was 0.93 mm per 1 cm³ orbital volume enlargement diameter[35]. Two of our patients had at the end of the postoperative evaluation period a residual enophthalmos that reached 3 mm. This may be attributed delayed or inadequate reduction of the ZMC fracture, failure to identify and restore the anatomy of the postero-medial bulge which is essential in maintaining the proper position of the globe, inadequate implant augmentation of this critical area. Inaccurate restoration of the medial orbital wall anatomy especially at its posterior part. The residual defects are usually located at the posterior medial wall that is defined as the key area that could be found on CT examination and is considered to be the most important cause of enophthalmos. The orbital bulge is an area of special importance; it is called the key area, as it diverges anteriorly and posteriorly forming with the posterior lateral wall the main support of the anterior projection of the globe[5,9,26]. The technical difficulties in identifying and reconstructing this area were due to limited access, poor visualization, complex anatomy[26] and the close proximity to the optic nerve.

**CONCLUSION**

These following clinical points was noted and should be emphasized: the importance of preoperative ophthalmological examination in management decisions, the importance of adequate exposure of orbital defects for proper implant placement and the correct positioning of the implant on stable ledges of bone is critical. Any type of implant will not serve its purpose if not placed anatomically.

The use of preformed implants for orbital floor and medial wall reconstruction saves time and renders traumatic intraoperative bending and adjustment of the implants unneeded, which is of particular importance in cases of polytrauma. However non-statistically significant differences were found between it and the custom individually computer assisted implants which is probably not necessary for routine use in small orbital blowout fractures but will be preferable specially in bilateral cases, malunion delayed healing cases, complex orbital injuries and postablative orbital defects.
REFERENCES


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