Radiological evaluation of sphenozygomatic suture fixation for restoration of orbital volume: A retrospective study

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ABSTRACT

Purpose: Lateral displacement of fracture zygomaticomaxillary complex (ZMC) can cause significant increase in orbital volume leading to enophthalmos. The aim of this study was to radiologically evaluate the efficacy of sphenozygomatic (SZ) suture fixation for restoration of orbital volume after elevation of the temporalis in cases of fracture ZMC where the fixation of zygomatic arch (ZA) was deemed necessary through latero-posterior approach.

Materials & methods: 43 operated cases of fracture ZMC using 4-point fixation were divided into two groups. Group I (n = 24) cases had undergone reduction and fixation of SZ suture as fourth point of fixation by elevating temporalis muscle using hemicoronal approach. Group II (n = 19) cases had undergone reduction and fixation of Infraorbital (IO) rim as fourth point of fixation using preseptal transconjunctival approach. Both the groups were analyzed separately and compared for restoring the increased orbital volume on CT.

Results: Difference in the pre-surgical orbital volume of both the groups was found to be statistically insignificant [p = .678]. In group I, the average bony orbital volume significantly reduced by 3.6 cc from 25.5 cc to 21.9 cc [p = .000] post-surgically. In group II, the average bony orbital volume reduced by 1.5 cc from 25.6 cc to 24.1 cc post-surgically. There was a significant difference in the reduction of the increased orbital volume among the 2 groups (Group I: 3.6 cc, group II: 1.5 cc). The amount of reduction was more and statistically significant [p = .000] in the group I than group II.

Conclusion: SZ suture fixation is reliable in reducing fractures ZMC and restoring the increased orbital volume where the fixation of zygomatic arch (ZA) was deemed necessary through latero-posterior approach.

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1. Introduction

The zygomatic bone is the most prominent bone in the upper lateral midface. The bone is solid and acts as a vertical and horizontal buttress. The fractures involving the zygoma are not usually confined to its strict anatomical boundaries but most often extend into adjacent maxillary and orbital structures. Therefore an appropriate terminology is Zygomaticomaxillary complex (ZMC) fractures (Ellis and Kittidumkerng, 1996). Fractures of the zygomatic arch (ZA) are often associated with ZMC fractures, but can also occur in isolation. Clinical sign and symptoms vary depending upon the type, extent, and degree/vector of displacement. Displacement of ZMC laterally along the vertical axis can cause significant increase in orbital volume, leading to enophthalmos. High-resolution computed tomography (CT) scans in axial, coronal, and sagittal sections with bone and soft tissue window provide a complete radiological visualization of the fracture, especially at the sphenozygomatic (SZ) suture region (Alsuhaibani, 2010). A step-ladder concept for ZMC and isolated arch fracture repair encompasses a variety of surgical routes from limited exposure to...

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extended access according to the degree of fracture severity. The location and displacement of the fracture sites define the type and number of approaches needed to adequately treat a given ZMC fracture. The osteosynthesis concept also influences the treatment plan. Non-comminuted medially displaced ZMC fractures are typically approached anteriorly applying a 1- to 3-point fixation concept, depending on the degree of displacement, whereas comminuted laterally displaced fractures often require extended craniofacial approaches. The SZ suture line is ranked as the most reliable positioning guide in the reduction of isolated fractures of ZMC or in the rebuilding of the outer facial frame in major midface or panfacial trauma (Manson et al., 1999). Even if the zygomatico-maxillary buttress and the infraorbital (IO) rim are highly fragmented, comminuted, or present with bony defects, it is still possible to reduce the zygoma exactly by gap and pivot control at the SZ junction. In theory, 28 combinations of a 1-point up to a 5-point plating pattern exist. The indications to open and fix (IO) rim in fracture ZMC are the need for exploration of the orbital floor and comminution zones at the lower vertical/inner horizontal buttresses (Cornelius, 2012). The purpose of this study was to evaluate the accuracy of SZ suture fixation after elevation of the temporalis muscle in cases of fracture ZMC in which the fixation of ZA was deemed necessary through a lateroposterior approach.

This is the first study on the SZ suture fixation in ZMC fractures in the existing oral and maxillofacial surgery literature. The study was based on the hypothesis that reduction and fixation of SZ suture would restore the increased volume of the bony orbit to its pre-injury state. The objectives were to measure the decrease in the increased volume of the bony orbit on CT and to draw a comparison with cases in which the above technique was not used.

The ideal orbital volume measurement method should be easily available, have a short learning curve, and take less time to perform. Various segmentation techniques are used for measurement of orbital volume, namely manual, threshold based, atlas based, and model based. Manual segmentation is an accurate technique in skilled and experienced hands in which the margins of the orbit are marked by the user in each image slice (Charteris et al., 1993; Lukats et al., 2012; Regensburg et al., 2008; Smith et al., 2007).

2. Materials and methods

An analytical, single-surgeon, retrospective study was designed from a population of patients who underwent fixation for fracture ZMC from 2008 to 2015. Institutional ethical committee approval was obtained before undertaking the study. Patients 18 years or more of age with 4-point fixed cases of fracture ZMC in which the fixation of ZA was deemed necessary through a lateroposterior approach with adequate pre- and postsurgery (CT) records available were included. The following criteria mandated fixation of zygomatic arch: (1) multifragmentation of the arch with lateral displacement of the middle section; and (2) fracture of the temporal arch root with tendency to telescope posteriorly. The following patients were excluded from the study: (1) patients with ZMC fractures in whom orbital floor reconstruction was required (in cases of disruption of internal orbit leading cosmetic deformity, soft tissue/muscle herniation and positive forced duction test) or carried out; (2) patients with any other midface fracture contributing to the change in the bony orbital volume; (3) patients with facial asymmetry; (4) patients with any previous history of fracture midface; (5) patients with impacted/medially rotated fracture ZMC where the volume of the bony orbit was decreased; and (6) patients with obvious misregistration artifacts on CT images. A hemicoronal approach was used to fix the zygomatic arch and frontozygomatic (FZ) suture region and upper vestibular approach for zygomatic buttress (ZB) region. In addition, either a preseptal transconjunctival incision was placed to address the IO rim as the fourth point of fixation (Fig. 1) or an SZ suture was reduced and used as the fourth point of fixation after elevating the temporalis muscle (Fig. 2). The choice of fourth point fixation was the IO rim only until 2012, after which the concept of sphenozygomatic reduction and fixation came into existence (Cornelius, 2012). All patients had undergone non-contrast-enhanced CT examination performed with a helical 16-slice Siemens Somatom Sensation 16 (Siemens, Erlangen, Germany). The images were obtained with 0.6-mm collimation, 1-mm thickness, and 1-mm increment at 180 mAs and 100 kVp. Each examination consisted of 25–30 contiguous slices through the orbit of patients; the axial sections were obtained at 0–10° from the orbito-meatal baseline. The patients were advised to fix their gaze at a point in the overhead gantry throughout the scan. Pixels representing area of interest in the structure within the prescribed density range were selectively counted. All of the bony apertures including the superior and inferior orbital fissures and the optical canal were excluded by drawing a line across them. A straight line connecting the medial and lateral orbital rims was designated as the anterior boundary of the orbit. The scan data were reformatted in the coronal and sagittal planes. The sectional area of the orbit was measured in each slice, and the orbital volume was calculated using the built-in image-measuring software in the system B (Fig. 3). A t test and paired t test were performed to assess the efficacy of each group in reducing the increased bony orbital volume and to draw comparisons between the two groups.

3. Results

A total of 43 documented records of 4-point fixation for fracture ZMC were identified as per the study criteria and divided into two groups. There was only one female patient in the entire study sample, with a 21.2-cc orbital volume of the unaffected eye. The average age was 31.14 years (range = 23–47 years, SD = 6.87) in the study sample. The average bony orbital volume of the unaffected side was 21.4 (range = 21.4–21.8 cc, SD = 0.4). Group I (n = 24) cases had undergone reduction and fixation of SZ suture as fourth point of fixation by elevating temporalis muscle using hemicoronal approach after reduction and fixation of ZA. Group II (n = 19) cases

Fig. 1. Reduction and fixation of IO rim using preseptal transconjunctival approach.
had undergone reduction and fixation of (IO) rim as fourth point of fixation using a preseptal transconjunctival approach. Difference in the presurgical orbital volume of both the groups was statistically nonsignificant [Sig. (2-tailed) = .678] (Table 1). In group I, the average bony orbital volume significantly reduced by 3.6 cc from 25.5 cc to 21.9 cc [Sig. (2-tailed) = 0.000] postsurgically (Fig. 4, Table 2). In group II, the average bony orbital volume was reduced by 1.5 cc from 25.6 cc to 24.1 cc [Sig. (2-tailed) = 0.000] postsurgically (Fig. 5, Table 3). There was a significant difference in the reduction of the increased orbital volume between the 2 groups (Group I: 3.1 cc; group II: 1.5 cc). The unpaired t test revealed that the amount of reduction was greater and statistically significant [Sig. (2-tailed) = 0.000] in group I than in group II (Table 4).

### 4. Discussion

Despite many publications on the epidemiology, incidence, and etiology of ZMC fractures, there is still a lack of information about a consensus in its treatment (Forouzanfar et al., 2013). Severely dislocated, laterally displaced, comminuted ZMC fractures in which the ZA arch has to be addressed typically require a wider exposure, mostly by a combination of anterior and posterior approaches, for adequate reduction and fixation. This can be a 4-point or a 5-point fixation (Cornelius, 2012). Such cases are encountered very often in developing nations where two wheelers are the mainstay for daily commuting, accidents resulting in severe high energy midface fractures. All 43 cases in groups I and II required 4-point fixation. ZMC fractures are almost always associated with fractures of the internal orbit. The ZMC fractures cause various degrees of comminution of the orbital floor. The increase in the orbital volume can result from orbital floor disruption or rotation of zygoma along with its articulations. The orbit should be addressed only in the cases in which it is deemed important to address the defect as per the size and clinical finding. The preoperative CT scan can be used to assess the amount of internal orbital disruption for purposes of developing a treatment plan in patients with ZMC fractures. Where there is minimal or no soft tissue herniation and there is minimal disruption of the internal orbit, ZMC reduction is adequate treatment (Ellis and Reddy, 2004). This was originally suggested by Manson et al., who
discussed how CT scans can be used to determine the amount of intervention that is necessary to satisfactorily treat midface fractures (Manson et al., 1990). In both groups, patients with ZMC fractures in which orbital floor reconstruction was required were excluded from the study, as were patients with any of the other factors that might contribute to change in the bony orbital volume. The IO rim is routinely assessed for reduction of fracture ZMC and is fixed by many surgeons in a 4-point fixation scheme. The reason for use of the infraorbital rim as an additional route of fixation is comminution zones at the lower vertical/inner horizontal buttresses (Cornelius, 2012). The drawback for using a pre-septal transconjunctival approach to assess the infraorbital rim is ectropion or increased scleral show (Ridgway et al., 2009). The IO rim is considered to be a less reliable landmark to assess the reduction of fracture ZMC and less stable for fixation (Cornelius, 2012); however, despite all of these drawbacks, it is routinely used by many (Forouzanfar et al., 2013). With the advent of intraoperative CT, many surgeons have preferred first to reduce the fracture ZMC and, if required, to explore the orbit. Intraoperative three-dimensional C-arm imaging appears to be an effective tool for evaluating ZMC fracture reduction. It helps to avoid additional procedures and thus helps to reduce morbidity. In addition, there appears to be no need for postoperative imaging (Wide et al., 2013). In medium-energy fractures, emphasis is given on confirming the SZ suture region reduction before fixation of FZ suture region (Ellis and Perez, 2014). Cadaveric studies have demonstrated the efficacy of SZ suture reduction in restoring the orbital volume and positioning the zygoma (Rohner et al., 2002). Plating the lateral orbital wall after elevation of the temporalis muscle is rarely indicated and is reserved for those extreme injuries that displace the adjacent skull base (Cornelius, 2012). This concept of reducing and fixing the SZ suture region was used for the first time by the surgeon (R.S.) to restore the bony orbital volume in laterally displaced fracture ZMC where the fixation of ZA was deemed necessary through a lateroposterior approach. The temporalis originates from the parietal bone of the skull and the superior temporal surface of the sphenoid bone. Only minimal stripping and elevation of the muscle is required to fix the SZ suture; thus there is no chance of developing temporal hollowing. The average orbital volume measured by CT scan is variable, as seen in different studies. Forbes et al. (1985) showed the normal average orbital volume to be 23.9 cc in males and 23.6 cc in females. A Japanese study by Furuta, 2001 revealed the orbital volume to be 23.6 cc in men and 20.9 cc in women. Deveci et al. (2000) reported a mean volume of 28.41 cc. Possibly this is due to differences in race, patient age, and measuring techniques. It has been observed that coronal CT scans underestimate the orbital volume by 6.9%–35.3%, depending on where the anterior limit of the orbit is taken (Kwon et al., 2010). Our study has revealed

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Pre- and postsurgery orbital volumes* (group I).</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Group I</td>
<td></td>
</tr>
<tr>
<td>Presurgical orbital volume (affected side in cc)</td>
<td>25.5</td>
</tr>
<tr>
<td>Postsurgery orbital volume (affected side in cc)</td>
<td>21.9</td>
</tr>
</tbody>
</table>

* Using paired t test: t = 14.9, df = 23, Sig. (2-tailed) = 0.000.

Fig. 4. Pre- and post orbital volumes in group I.
average orbital volume of 21.4 cc. It has been shown that right and left orbits have similar volumes and that the contralateral orbit can serve as a control for the affected orbit while monitoring patients in the postoperative period. The average orbital volume in the unaffected eye in 43 cases was 21.4 cc. There was no statistical difference between the preoperative orbital volumes of the affected sides in the two groups. Thus the efficacy of each group was easily computed and compared after assessing the postoperative results. In group I, the average bony orbital volume achieved after reduction is 21.9 cc, which is very close to the bony orbital volume of the unaffected eye. However, in group II, the reduction of the orbital volume (1.5 cc) was less, and the difference with the average unaffected orbital volume was 3.6 cc. It has been argued that there is no significant difference between orbital volume on either side and that the contralateral orbit can be used as a control for comparison of the orbital volume. On the other hand, few studies have mentioned that volumes of orbits may differ by 7 to 8% (Grove et al., 1978). Studies have demonstrated that about a 1-cc increase in orbital volume results in about 1 mm of enophthalmos (Whitehouse et al., 1994; Ploder et al., 2002). Clinically perceptible enophthalmos does not usually occur until there has been at least 3 cc of orbital volume increase. Although estimation of enophthalmos is beyond the scope of this article, one should keep in mind the above-stated fact that 3.6 cc of resultant enophthalmos can cause clinically persistent sunken eyes postfixation of fracture ZMC in cases in which the fixation of zygomatic arch (ZA) was deemed necessary through latero-posterior approach.

Table 3
Pre- and postsurgery orbital volumes* (group II).

<table>
<thead>
<tr>
<th>Group</th>
<th>Presurgical orbital volume (affected side [cc])</th>
<th>Mean</th>
<th>n</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group II</td>
<td></td>
<td>25.6</td>
<td>19</td>
<td>.55</td>
</tr>
<tr>
<td></td>
<td>Postoperative orbital volume (affected side [cc])</td>
<td>24.1</td>
<td>19</td>
<td>.25</td>
</tr>
</tbody>
</table>

* Using paired t test: $t = 7.8$, df = 18, Sig. (2-tailed) = 0.000.

Table 4
Comparison of the reduced volumes* (groups I and II).

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>24</td>
<td>3.6</td>
<td>0.2</td>
</tr>
<tr>
<td>II</td>
<td>19</td>
<td>1.5</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* Using unpaired t test: $t = 8.9$, df = 41, Sig. (2-tailed) = 0.000.

5. Conclusion

If any case requires zygomatic arch fixation in a laterally displaced comminuted ZMC fracture instead of approaching the IO rim as the fourth point of fixation or for adequate reduction in the increased orbital volume, we recommend reduction and fixation of the SZ suture, which will not require any additional exposure. This technique should be used only if the arch has been exposed for fixation.

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References
