Long term results following immediate reconstruction of orbital fractures: A critical morphometric analysis

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M Dawar, OM Antonyshyn. Long term results following immediate reconstruction of orbital fractures: A critical morphometric analysis. Can J Plast Surg 1993;1(1):24-29. The purpose of this study is to review the long term morphological results following primary reconstruction and bone grafting of orbital fractures. All patients presenting to the Victoria General Hospital in Halifax, Nova Scotia between July 1988 and December 1990 with orbital fractures of sufficient severity to require immediate reconstruction were included in the study. The series consists of 39 fractured orbits in 29 patients. In all patients, a standardized data sheet was used in recording patient demographics, and clinical and intraoperative findings. The surgical management of orbital fractures and in particular the redraping of periorbital soft tissues was performed according to a standard protocol. Long term morphometric assessment was performed between 11 and 38 months postoperatively, with a mean follow-up of 27 months. A McCoy facial trisquare and Hertel exophthalmometer were used in the anthropometric evaluation of ocular globe position and position of the periorbital soft tissue landmarks. Postoperative assessment of globe position revealed a 5% incidence of enophthalmos and an 11% incidence of hyperophthalmia. Minor asymmetries in globe position measuring less than 2 mm were noted in a further 61% of patients. Ectropion was documented in 8% of patients, but an asymmetry in the height of the palpebral fissure was noted in a further 34% of patients. In terms of canthal relations, lateral canthal dystopia was the most commonly observed deformity, with vertical dystopia occurring in 18% of patients and transverse dystopia in 33% of patients. The observed sequelae and complications of orbital fractures are discussed and possible causative factors identified.

Key Words: *Morphometric analysis, Orbital fractures, Reconstruction*

Résultats à long terme suite à la reconstruction immédiate de fractures orbitales: analyse morphométrique critique.

RÉSUMÉ: Le but de cette étude est de passer en revue les résultats morphologiques à long terme, de la reconstruction primaire et de la greffe osseuse de fractures orbitales. Tous les patients qui se sont présentés au Victoria General Hospital de Halifax entre juillet 1988 et décembre 1990, atteints de fracture orbitale d'une gravité qui justifie une reconstruction immédiate, ont été inclus dans l'étude. Cette série comprend 39 orbites fracturées chez 29 patients; chez tous les patients une feuille de renseignements standardisée a été utilisée lors de l'enregistrement des données démographiques et cliniques ainsi que des observations peropératoires. Le traitement chirurgical des fractures orbitales et en particulier le redrapage des tissus mous péri-orbitaux ont été effectués selon le protocole standard. Une évaluation morphométrique à long terme a été effectuée entre le onzième et le trente-huitième mois suite à l'opération. Le suivi a été fait sur une période moyenne de 27 mois. Le trisquare facial de McCoy et l'exophthalmomètre de Hertel ont été utilisés pour l'évaluation anthropométrique de la position du globe oculaire et de la position des repères au niveau des tissus mous péri-orbitaux. L'évaluation post-opératoire de la position du globe a révélé une incidence de 5% de l'enophtalmie et de 11% de l'hyperophtalmie. Des asymétries mineures au niveau de la position du globe, mesurant moins de 2 mm, ont été notées chez 61% des patients. L'ectropion a été documenté chez 8%, mais une asymétrie au niveau de la fente palpébrale a été notée chez encore 34% des patients. En terme de relations canthales, la dystopie canthale latérale a été la plus fréquemment observée des difformités, avec une dystopie verticale chez 18% des patients et une dystopie transverse chez 33% d'entre eux. Les séquelles et complications observées au niveau des fractures orbitales sont présentées et certains facteurs possiblement en cause sont identifiés.

Current management of orbital trauma aims to restore the normal skeletal anatomy of the orbit and to re-establish the palpebral and canthal relations of periorbital soft tissues. Recent developments in facial trauma surgery have greatly facilitated the realization of these goals. The adaptation of craniofacial surgical techniques allows complete exposure

of the facial skeleton and precise reduction of fractures under direct visualization. Rigid internal fixation provides optimal three-dimensional stability in the reconstructed orbital framework. Most importantly, primary repair of skeletal defects within the orbital cavity is effective in restoring orbital volume and minimizing subsequent problems with strabismus or enophthalmos.

Despite the dramatically increased precision in skeletal reconstruction offered by these techniques, residual post-traumatic deformities featuring asymmetries in the position

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Figure 1) Forty-seven-year-old patient following a right orbitozygomatic fracture. **Left** Schematic diagram indicates the position of internal fixation devices and orbital bone graft employed in the reconstruction. **Right** Late postoperative result. Despite restoration of normal facial width, malar projection and orbital volume, residual asymmetries in periorbital soft tissues are apparent. The right globe is inferiorly displaced, palpebral fissure height is increased and a lateral canthal dystopia is noted

or projection of the ocular globes, abnormalities in palpebral fissure dimensions or inclination, canthal dystopias and ectropion are still observed (Figure 1).

This study reviews the long-term morphological results of immediate reconstruction in orbital fractures. Data generated by follow-up morphometric assessments are presented and analyzed to describe residual post traumatic asymmetries, disproportions and abnormalities in the location of the ocular globes and periorbital soft tissues. Specific problems are identified and causative factors are discussed.

MATERIAL AND METHODS

The series

Between July 1988 and December 1990, 51 consecutive patients presented to the Victoria General Hospital, Halifax, Nova Scotia with orbital fractures of sufficient severity to require immediate reconstruction, using open reduction, rigid fixation and primary bone grafting techniques. Of these patients, 29 returned for long term follow-up assessment and comprise the series of the present study. Patients ranged in age from 16 to 61 years, with a mean age of 32 years. Ten were female and 19 were male. Ten patients had bilateral

orbital fractures requiring reconstruction. The analysis of results is therefore based on 39 fractured orbits in 29 patients.

Data collection

A standardized data sheet was designed to record details of patient demographics, mechanism of injury, and initial clinical and ophthalmological findings. Standard skull diagrams were further employed in describing orbital fracture patterns, based on both radiological and intraoperative findings, and in recording the details of operative reconstruction. The data sheet was filled out for each patient at the time of initial clinical assessment and immediately postoperatively.

Surgical technique

All patients included in this series were treated by the senior author, according to a standard protocol previously established for the repair of complex orbital fractures (1). Appropriate incisions were used as required to permit complete subperiosteal dissection of the involved regions of the orbit. Fractures of the orbital rim were reduced anatomically under direct visualization, and rigidly fixed with contoured miniplates and screws. Defects in the bony rim of the orbit were immediately reconstructed with fixed inlay bone grafts

Figure 2) The McCoy trisquare is a transparent facial plate which serves as a reference grid to permit localization of facial landmarks and quantitative morphometric assessment. The Y axis is oriented along the facial midline while the X axis is oriented along the canthal line (transverse axis through the lateral canthus)

to restore bony continuity and ensure a stable three dimensional skeletal framework.

Exploration of the orbital cavity ensured retrieval of all prolapsed soft tissue contents and identification of intact bony shelves posterior, medial and lateral to the orbital defect or defects. All cavity defects were reconstructed primarily, using nonfixed grafts. The support offered by the stable shelves of the defect and the tamponading effect of intraorbital contents were relied upon for graft stability. Autogenous material was consistently employed. The choice of donor material, ie, cartilage graft or bone harvested from the skull, antrum or iliac crest, was dictated by the shape, size and location of the orbital defect.

The redraping of soft tissues was facilitated in the following fashion. In the presence of traumatic telecanthus, the position of the medial canthal ligament was re-established by reduction and fixation of the attached nasomaxillary fracture fragment, if large enough, or alternatively by transnasal canthoplasty. The soft tissues of the cheek were suspended from drill holes in the infraorbital rim by suture fixation of cheek periosteum to prevent subsequent cheek ptosis or lower lid ectropion. Lateral canthoplasty was performed when subperiosteal dissection of the lateral orbit was extensive, and in conjunction with coronal flap elevation.

Morphometric assessment

Patients were asked to return for clinical evaluation of long term results. The time interval between surgery and follow-up assessment varied from 11 to 38 months, with a mean follow-up of 27 months. All findings were recorded on a standard data sheet.

Morphometric assessment of the position of the canthi, palpebral fissures and ocular globes were performed using the McCoy facial trisquare (Figure 2). This transparent face plate was fitted over the patient's face, providing vertical and horizontal reference scales. Standard facial antero-posterior (AP) photographs were then taken at a fixed focal distance.

Figure 3) Method of periorbital morphometric analysis. **Top** Anthropometric landmarks are first identified. G Globe (midpoint of pupil); ps Palpebrae superioris (highest point on ciliary margin); pi Palpebrae inferioris (lowest point on ciliary margin); en Endocanthion; ex Exocanthion; M Facial midline; CL Canthal line. **Bottom** The position of each periorbital landmark is noted relative to the midline (M) and canthal line (CL). In addition, the following distances are measured: PFH Maximum height of the palpebral fissure; PFW Maximum width of the palpebral fissure; SS Maximum scleral show

Subsequent analysis required identification of the anthropometric landmarks on the photographs, and direct measurements relating these landmarks to the facial midline and the canthal line (horizontal reference line between the lateral canthi [Figure 3]).

Forward projection of the globes was further assessed with the Hertel exophthalmometer. Measurements were expressed in millimetres of corneal projection anterior to the lateral orbital rims. This technique uses the lateral orbital rims as a reference and is not reliable if the lateral rims are disrupted or asymmetrical. However, in the present series all orbital rim fractures had previously been reduced and fixed anatomically, and this method of measurement was therefore considered valid.

Data analysis

All collected data were entered in a customized computer database program. Morphometric analysis required identification of periorbital landmarks, and the entering of X and Y coordinates for each landmark, relative to the facial midline and canthal line. The software program was designed to identify automatically significant asymmetries, disproportions or deformities in the location of periorbital landmarks when compared to normal anthropometric data (2).

RESULTS

Characteristics of the trauma population

Twenty-nine patients with orbital fractures were included in the series. The majority of patients (86%) sustained high velocity injuries to the face, commonly resulting from motor vehicle accidents (72.4%) and industrial trauma (7%). Multi-

Figure 4) Orbital fracture patterns. The total number of fractures and the frequency of comminution and bony deficiency are noted for each anatomical site. Data pertaining to orbital rim fractures are presented in the orbit on the left. Data describing fractures of the orbital cavity are presented in the orbit on the right

TABLE 1: Orbital soft tissue trauma

	Incidence (%) (n=39 orbits)
Optic nerve injury	2
Globe rupture	8
Retinal tear	5
Corneal abrasion	2
EOM entrapment	23

EOM Extraocular muscle

TABLE 2: Ocular globe projection and position

Morphological features	Definition	n=37 orbits	n=28 patients
Projection			
Enophthalmos	(GP < 14 mm) or (> 2 mm difference)	5	
Proptosis	(GP > 17 mm) or (> 2 mm difference)	0	
Minor asymmetry	0 mm < difference in GP < 2mm		28
Position			
Ptosis	G/Cl < 0 mm	3	
Hyperophthalmia	G/Cl > 3 mm	11	
Minor asymmetry	0 mm < difference in G/Cl < 2 mm		61

GP Globe projection; G/Cl = Globe position relative to canthal line

system trauma was documented in 41% of patients and significant head injuries were noted in 21% of cases.

Fractures of the orbit were observed in isolation in only five patients. Most patients in this series sustained high velocity injuries with concomitant fractures of adjacent facial bones. Associated fractures of the maxilla, nasoethmoid and craniofrontal regions were documented in 59%, 41% and 10% of patients, respectively.

Orbital soft tissue trauma

The present study reviews 39 orbital fractures in 29 patients. The overall incidence of injuries to the orbital soft tissue

Figure 5) Hyperophthalmia following reduction fractured right zygoma and bone graft to right orbital floor. **Top** The McCoy trisquare confirms a significant (4 mm) elevation of the right ocular globe. **Bottom** A postoperative three dimensional CT scan reveals an excessively thick bone graft in the right orbital floor

contents was high (Table 1). Thirteen per cent of fractures were associated with major trauma to the ocular globe, including retinal tears (5%) and globe ruptures (8%). The extent of globe disruption necessitated enucleation in two cases, while one lacerated globe was successfully repaired and preserved.

Strabismus was documented in 59% of patients at initial presentation. However, only 23% of orbital fractures were associated with an obvious mechanical restriction or entrapment of extraocular muscles.

Orbital skeletal trauma

Orbital fracture patterns were described on the basis of radiological and intraoperative findings. For purposes of description, the orbit was divided into superior, inferior, medial and lateral anatomical segments. The orbital cavity and the circumferential bony rim of the orbit were evaluated separately. Fractures were considered comminuted if more than two fracture lines were observed in a given anatomical region. A gap in bony continuity in a given anatomical site requiring bone graft reconstruction was recorded as a skeletal defect.

The observed fracture patterns in this population are summarized in Figure 4. High velocity orbital trauma usually resulted in disruption of the orbital rim. The inferior and lateral orbital rims were most commonly involved. While a single fracture line at the frontozygomatic articulation was characteristic of lateral rim fractures, inferior rim fractures featured multiple displaced and unstable segments in 29% of

Figure 6) Left lower eyelid ectropion following a subciliary approach to an orbital floor fracture. Scleral show and an increased height of the palpebral fissure are demonstrated. Note that ocular globe position and lateral canthal position are symmetrical

cases, and comminution of sufficient severity to require immediate bone grafting in a further 10% of cases. The supra-orbital rim is comparatively resistant to trauma and was rarely injured. However, forces of sufficient severity to disrupt the superior rim consistently resulted in severe comminution.

Fractures of the orbital cavity were inevitably observed in association with orbital rim disruption. The orbital floor was most commonly involved. The frequency and degree of comminution was consistently higher in all regions of the orbital cavity, as compared to corresponding regions of the bony rim. Virtually all comminuted fractures within the orbital cavity required graft reconstruction.

Morphometric analysis of postoperative results

Globe projection: Exophthalmometry was performed in 28 of 29 patients. One patient underwent bilateral enucleations as a result of globe disruption and was excluded.

Significant enophthalmos (absolute corneal projection less than 14 mm, or relative retrusion greater than 2 mm as compared to the contralateral globe) was documented in two patients on long term follow-up (Table 2). Causative factors were identified on follow-up computerized tomographic (CT) scans. Although the reconstruction of the fractured zygoma and anterior orbit were anatomical in both patients, the bone grafts failed to restore skeletal deficiencies in the posterior aspect of the inferomedial orbit.

A discrepancy in ocular globe projection was further documented in an additional eight patients. Although none of these patients presented with a clinically significant enophthalmos or proptosis, an asymmetry in globe projection varying from 0.5 mm to less than 2.0 mm, with a mean of 1.1 mm, was identified. Most of these minor asymmetries (90%) featured a retrusion of the ocular globe within the reconstructed orbit. One patient developed a relative protrusion of 1 mm, due to overcorrection of the volume deficit in the reconstructed orbit.

TABLE 3: Palpebral and canthal relations

Morphological feature	Definition	Incidence (%) n = 39 fractured orbits
Medial canthus		
Vertical dystopia	$1 \text{ mm} < \text{En/Cl} < 3 \text{ mm}$	5
Telecanthus	$\text{En/M} \geq 18 \text{ mm}$	25
Lateral canthus		
Vertical dystopia	$2 \text{ mm} < \text{Ex/Cl} < 2 \text{ mm}$	18
Transverse dystopia	$58 \text{ mm} < \text{Ex/M} < 43 \text{ mm}$	33
Palpebral fissure		
Ectropion	$\text{SS} > 1 \text{ mm}$ or $\text{PFH} > 13.5 \text{ mm}$	8

En Endocanthion; Cl Canthal line; M Facial midline; Ex Exocanthion; SS Maximum scleral show; PFH Maximum height of the palpebral fissure

TABLE 4: Periorbital asymmetries

Morphological feature	Definition	Incidence (%) n = 29 patients
Medial canthus		
Vertical asymmetry	Difference in $\text{En/Cl} > 2 \text{ mm}$	3
Transverse asymmetry	Difference in $\text{En/M} > 2 \text{ mm}$	17
Lateral canthus		
Vertical asymmetry	Difference in $\text{Ex/Cl} > 2 \text{ mm}$	21
Transverse asymmetry	Difference in $\text{Ex/M} > 43 \text{ mm}$	21
Palpebral fissure		
Vertical asymmetry	Difference in $\text{PFH} > 2 \text{ mm}$	34

En Endocanthion; Cl Canthal line; M Facial midline; Ex Exocanthion; PFH Maximum height of the palpebral fissure

Globe position: Globe position was studied in 28 patients with intact globes. Vertical ocular displacement was considered significant if the absolute position of the midpupil was located below the canthal line, or greater than 3 mm above the canthal line, or if there was a discrepancy of greater than 2 mm between the two globes.

Given this definition, significant deformities in ocular globe position were observed in 14% of patients (Table 2). Ptosis of the ocular globe was rare and was documented in only one patient. However, supradisplacement (hyperophthalmia) was observed in four cases. Follow-up coronal CT scans in all four consistently demonstrated overcorrection of anterior orbital floor defects by excessively thick or inappropriately contoured bone grafts (Figure 5).

A minor asymmetry in ocular globe position was a much more common finding in reconstructed orbits. Although not presenting with a clinically obvious deformity, 61% of patients were found to have a discrepancy in the vertical position of the midpupils measuring between 0.5 and 2 mm. The asymmetry was characterized by an inferiorly displaced globe in the reconstructed orbit in nine cases, and a superiorly displaced globe in five cases, relative to the contralateral intact orbit. In the remaining three patients, bilateral orbital

fractures precluded any determination of the direction of globe malposition.

Palpebral relations: For the purposes of this study, ectropion was identified in patients with scleral show greater than 1 mm, or palpebral fissure height greater than 12.5 mm (Figure 6). In a series of 39 orbital fractures, all of which required an exposure of the inferior orbit, three cases (8%) developed an ectropion of the lower eyelid (Table 3). Two of these were associated with a lateral canthal dystopia.

Although the palpebral fissure dimensions were within a normal range in the remaining population, an asymmetry in the height of the palpebral fissure was documented in a further 10 cases (34% of patients) (Table 4). Of these, two were associated with enophthalmos and pseudoptosis, while six were associated with an asymmetry in the position of the lateral canthi.

Canthal relations: The medial and lateral canthal positions determine both the width and inclination of the palpebral fissures. Minor discrepancies in position produce obvious periorbital deformity or asymmetry.

Nasoethmoid fractures associated with telecanthus were documented in 12 of 39 fractured orbits. Anatomical reduction was effective in correcting canthal displacement in most cases, with residual vertical dystopia and telecanthus noted in two cases and one case, respectively (Table 3).

Lateral canthal dystopia was more frequently observed, with significant vertical or transverse dystopia noted in 18% and 33% of fractured orbits respectively (Table 3). Asymmetries in lateral canthal position were documented in an additional 21% of patients (Table 4).

DISCUSSION

Increasing sophistication in the surgical technique of orbital exposure, bone grafting and fracture fixation provide the surgeon with unprecedented control over the restoration of skeletal anatomy. Despite improved results of orbital skeletal reconstruction, obvious residual post traumatic deformity is still observed in many patients. This study reviews the long term morphological results of orbital fracture treatment in an effort to identify and characterize common deformities.

The three-dimensional projection and position of the ocular globe reflects the accuracy in restoration of normal dimensions of the orbital cavity following trauma. In 1987, Pearl (3) first described the importance of volumetric alterations of the orbital cavity relative to the axis of the globe. Failure to restore the volume of the orbit posterior to the axis of the globe results in enophthalmos. However, volumetric changes at or in front of the axis of the globe merely serve to change the vertical position of the globe.

In the present series, hyperophthalmia or superior displacement of the globe was the most commonly observed deformity in ocular position. The deformity was consistently due to a failure in reconstructing the anterior orbital floor anatomically. Bone grafts which are excessively thick or inadequately contoured in this area produce vertical displacement of the globe. Particular care should therefore be taken in shaping and thinning grafts employed in the reconstruction of orbital defects at the axis of the globe.

Ectropion has previously been noted as a complication of orbital fractures in 1 to 10% of cases (4). In the present series, a true ectropion was documented in 8% of cases but asymmetries in the height of the palpebral fissure were noted in an additional 34% of patients. This is one of the most commonly observed sequelae of orbital fracture reconstruction.

It is important to note that the height of the palpebral fissure is normally determined by multiple factors including ocular globe position and projection, lateral canthal position, and lower eyelid tone. Postoperative deformities can therefore result from alterations in any of these factors, in addition to cicatricial shortening of lower lid height.

Lateral canthal dystopia is another commonly observed sequela of orbital fracture repair, noted in 18% of our cases. This high complication rate occurred despite routine lateral canthopexy. Possible causative factors include inadequate localization of the lateral canthal tendon insertion point or subsequent disruption of the canthopexy. Stripping of the lateral canthus should probably be performed only when necessary for exposure. In the event that disinsertion is required, the precise location of lateral canthal attachment should be noted and marked, prior to subperiosteal stripping.

Morphometric analysis of the long term results of orbital fracture treatment reveals a significant incidence of post traumatic deformity and asymmetry, primarily in periorbital soft tissue structures. As craniofacial surgical techniques continue to evolve, both research and clinical efforts should focus on methods for improved localization and reinsertion of key periorbital landmarks and optimal redraping of soft tissues.

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