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Treatment of orbital blowout fracture using a customized rigid carrier

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SUMMARY

Purpose: This study aimed to examine the usefulness of treating orbital blowout fracture using a customized rigid carrier.

Material and Methods: Patients who underwent surgery for orbital blowout fractures in our department from April 2016 to March 2019 were recruited in the study. We molded a rigid thermoplastic material into the same shape as the reconstruction material according to the 3D model and transplant it into the orbital space along with the reconstruction material. We assessed Hertel exophthalmometry, awareness of diplopia, and the Hess area ratio (HAR%).

Results: We performed this procedure in 15 patients with blowout fractures. Reconstruction materials used were iliac bone, absorbable plates, and titanium mesh in 12, 2, and 1 patient, respectively. None of the patients showed a difference of more than 2 mm on Hertel exophthalmometry. Only one patient had diplopia after surgery. The average preoperative and postoperative HAR% was 83.1 and 90.6, respectively. HAR% was more than 85% in 6 of 7 postoperative cases.

Conclusions: This method can be applied for surgery using various reconstructive materials and can be a useful method, especially in patients with a wide range of orbital bone defects.

KEYWORDS

orbit, blowout fracture, three-dimensional model

INTRODUCTION

In orbital blowout fractures, reconstruction of the orbital wall is essential using autogenous bone, titanium mesh, or absorbable sheet. It is difficult to reconstruct the orbital wall extensively from the medial wall to the orbital floor and retain its original shape owing to its complicated anatomical structure. Recently, a technique for reconstruction of the orbit using a 3D model has been reported (Kozakiewicz M, 2009; Mustafa, 2011; Oh TS, 2016; Vehmeijer M, 2016; Raisian S, 2017; Kim YC, 2018; Pang SSY, 2018; Weadock WJ, 2019). In this technique, the 3D model is used for molding of the reconstruction material to be transplanted before and during surgery based on the morphology of the unaffected side; further, it is possible to reproduce a symmetrical orbital morphology. However, when the defect is extensive, it is difficult to implant the reconstructed material in an appropriate position while maintaining an appropriate shape. This is because the transplant material has a poor hardness and is deformed when an external force is applied during transplantation. Therefore, our department uses a method in which a rigid thermoplastic material is molded into the same shape as that of the reconstruction material according to the shape of the orbit and is transplanted into the orbital region along with the reconstruction material. This study aimed to examine the usefulness of this method.

MATERIAL AND METHODS

Ethical approval

This study was conducted in accordance with the Declaration of Helsinki. Due to the retrospective, non-interventional nature of the study, tacit consent was applied, and participants could opt out of the study via our website. The study protocol was reviewed and approved by an ethics committee.

Study subjects

Patients who underwent surgery for orbital blowout fractures in our department from April 2016 to March 2019 were recruited in the study. Patients in whom a rigid carrier was not used during surgery were excluded from the study.

Operating method

Before operation, a 3D model of a mirror image was created with the normal uninjured side and the injured side reversed from the computed tomography (CT) image. Based on the dimensions of the 3D model of the orbit, the implant material was simulated using a thermoplastic material (Aquaplast-T® 1.6 mm thick; SAKAI Medical Co., Ltd., Tokyo, Japan) (Fig. 1). At the time of surgery, the plastic was sterilized and brought to the surgical field. The transplant material was molded to match the plastic. The medial orbital wall and floor were approached percutaneously or transconjunctivally. The transcaruncular approach can be used for isolated medial orbital wall fractures. In cases with extensive bone loss from the medial wall to the floor, a combination of transcaruncular and retroseptal transconjunctival approach was performed to the orbital floor with the stripping of the inferior oblique muscle from its origin followed by suturing and repairing of the muscle stump with the periosteum at the point of attachment during wound closure. If there is no space to fix the inferior oblique muscle because the combined fracture of the orbital floor and medial wall extends to the front, reconstruction is not performed. After reducing the orbital contents into the orbit, the reconstruction material was implanted into the orbital bone defect using plastic as a rigid carrier. The thermoplastic material may be used simultaneously with the reconstruction material, or the plastic may be inserted into the orbital bed first and the reconstruction material implanted along with the same. After transplantation of the reconstruction material into the appropriate location, the plastic was removed. After confirming that there was no restriction on eye movement with the traction test, the periosteum was sutured and closed, followed by the closure of the skin. A facial CT scan was obtained immediately after the operation to clarify the positioning of the bone transplant.

Measurement

1) Hertel exophthalmometry was used to measure the difference between healthy and affected sides

2) Awareness of diplopia was checked in the top-bottom and right-left directions using the contraceptive method; if it was detected in any of the directions, diplopia was considered present (+).

3) The Hess area ratio (HAR%) is defined as the percentage of the square area of the affected side compared with that of the healthy side on the Hess chart (Furuta M, 2006). The Hess chart is an

inspection to measure the degree of eye movement limitation, and the side of the eye movement limitation has a narrower plot range. Length A (mm) between the upper and lower plots and length B (mm) between the left and right plots were measure at the center, 15°, or 30° of the affected eye on the Hess chart. The healthy eye was measured similarly (A' (mm) and B' (mm)). HAR% was calculated using the following equation; (A×B)/(A'×B')×100 (%). If the plot is outside the Hess chart, the length up to the outer border of the chart is substituted in the equation (Fig. 2). The lower the HAR%, the worse the eye movement limitation on the affected side.

Preoperative and postoperative measurements were obtained for all three parameters. The postoperative measurements were considered as the last available data that could be measured (1-7 months postoperatively).

CASE REPORTS

Patient 1

A 17-year-old man suffered a fracture of the right orbital medial wall and floor during sports. Open reduction was performed using a transconjunctival approach using the iliac bone. Postoperative complications were not observed. The postoperative difference on the exophthalmometer was 1 mm, and the postoperative HAR% was 97.2% (Fig. 3).

Patient 2

A 25-year-old woman suffered a fracture of the medial wall and floor of the right orbit from a traffic injury. Open reduction was performed via a transconjunctival approach using an absorbable material. The difference of 2.5 mm in the exophthalmometer before the operation disappeared after the operation. HAR% also improved from 71.1% to 87.5% (Fig 4).

Patient 3

A 63-year-old woman suffered a panfacial fracture from a traffic injury; after reduction of the zygomatic and maxillary fractures, she was found to have undergone extensive bone loss in the right orbit. Reconstruction was performed using a titanium mesh. The eyeball developed phthisis bulbi, for which the patient had to wear an ocular prosthesis; however, the orbital wall was accurately reproduced, and enophthalmos was minimized (Fig. 5).

RESULTS

Table 1 shows the results.

Demographics

There were a total of 26 cases of blowout fracture surgery, 11 of which were excluded. Among 15 patients who underwent surgery using this method, the iliac bone, absorbable plates, and titanium mesh were used as reconstruction materials in 12, 2, and 1 patient, respectively. Hertel exophthalmometry, diplopia awareness, and HAR% were obtained in 13, 14, and 7 patients, respectively.

Hertel exophthalmometry

Before surgery, a difference was observed in 10 of 13 patients, and 6 patients showed a difference of ≥2 mm. After surgery, a difference was observed in 2 of 12 cases, but no case showed a difference of ≥2 mm.

Awareness of diplopia

Before surgery, diplopia was observed in 7 of 14 patients. However, only one patient had diplopia after surgery.

Hess area ratio

The HAR% could be measured in 7 cases, and all cases showed improvement after surgery. The average preoperative and postoperative HAR% was 83.1 and 90.6, respectively. It was more than 85% in 6 of 7 postoperative cases.

DISCUSSION

This study showed that none of the patients showed a difference of ≥2 mm on Hertel exophthalmometry after the surgery. Further, only one patient had diplopia after surgery. The average HAR% was more than 85% in 6 of 7 postoperative cases. These findings implied the efficacy and safety of our technique.

The use of 3D models has become popular for surgical treatment of orbital blowout fractures. It is difficult to mold the reconstructed material into an appropriate shape owing to the complicated shape of the orbit. However, by using a 3D model, the shape can be easily adjusted to the defect. Many reports explain the use of titanium mesh (Kozakiewicz M, 2009 Mustafa, 2011; Oh TS, 2016; Raisian S, 2017; Kim YC, 2018), autogenous bone (Vehmeijer M, 2016), absorbable plates (Weadock WJ, 2019), and other materials (Pang SSY, 2018) for reconstruction using 3D models. A common technique for using a 3D model is to create a mirror image of the unaffected side and transplant the reconstruction material according to the shape; this method has been shown to reduce the operation time and improve the performance of the reconstruction form.

Another important factor in the reconstruction of blow-out fractures is the entire process of transplantation, including the material and the technique used to transplant the same. The reconstruction material must be implanted into the orbital floor in an appropriate shape. If the defect in the orbit is small, the task is not so difficult. However, in large defects, the orbital contents, such as the orbital fat, interfere with the placement of the reconstructed material, and transplantation often cannot be performed smoothly. When the transplant material is soft, caution must be exercised to avoid the deformation of the material. In this study, we used a thermoplastic material as a carrier during the transplantation. The material, which was shaped similar to the reconstructed shape, acted as a rigid carrier for the implanted material; hence, the reconstructed material was implanted without deformation.

Various materials, such as titanium, autogenous bone, or absorbable sheet, may be used for reconstruction, as shown in the study. However, when using autologous bone, a cancellous bone that can be deformed must be used (Sakakibara S, 2009). Autologous bone has many advantages such as biocompatibility, lower potential for extrusion, decreased foreign body reactions, and less infection risk (Sakakibara S, 2009; O'Connell JE, 2015). There are also disadvantages such as absorption and donor morbidity (pain, infection, sensory nerve disturbance, fracture, etc.) (Barone A, 2011; Dimitriou R, 2011; Kuik K, 2016). However, these studies reported low or no long-term donor site morbidity. Therefore, we used autologous bone most often.

According to the results of this study, none of the patients showed the left-right difference of ≥2 mm on Hertel exophthalmometry, which seems to reflect the accuracy of the reproducibility of the morphology, and it was considered that good reduction was obtained in all cases. The Hess area ratio is considered to be a useful index for eye movement (Furuta M, 2006 Grenga PL, 2009 Yamanaka Y, 2018), and no postoperative diplopia was observed in the case of preoperative HAR >85% (Furuta M, 2006; Grenga PL, 2016). In a previous study, patients with trap-door fractures who underwent surgery within 8 days had significantly better HAR than those who underwent surgery after 8 days, and the mean final HAR% was 92.9% (Yamanaka Y, 2018). The measured HAR% results for all cases in this study were improved in all cases, and only one patient showed HAR% results <85% postoperatively. Postoperative diplopia persisted only in 1 patient, which seemed to be a good result.

The disadvantage of this method was that a 3D model needed to be prepared in advance, and this technique cannot be used in patients requiring emergency surgery. However, this is true for all operations using 3D models. Further, when the defect range is small, this method may not be useful.

The major limitation of this study was the small number of cases. In addition, we were unable to compare our results with those of cases that did not use rigid carriers. Future studies are required to collect more data on this subject.

CONCLUSIONS

Here, we reported a surgical method using a customized rigid carrier for orbital blowout fractures. This method can be used with various reconstructive materials, such as titanium and autogenous bone, and would be useful, especially in patients with a wide range of orbital bone defects.

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Tables

Table 1.

No.	Age (yr)	Sex	material	Difference of exoophthalmometry pre-op (mm)	Difference of exoophthalmometry post-op (mm)	Awareness of diplopia pre-op	Awareness of diplopia post-op	HAR% pre-op	HAR% post-op
1	51	M	Iliac bone	3	0	-	-	-	-
2	79	F	Absorbable	0	0	+	-	-	-
3	29	M	Iliac bone	1	0	+	-	-	-
4	59	M	Iliac bone	0.5	0	+	+	78.6	89.5
5	66	F	Iliac bone	-	0.5	+	-	-	-
6	17	M	Iliac bone	2	1	-	-	90.7	97.2
7	25	F	Absorbable	2.5	0	-	-	71.1	87.5
8	17	M	Iliac bone	0	0	+	-	90	94.7
9	30	F	Iliac bone	1	0	-	-	91.7	97.2

10	19	M	Iliac bone	2	-	-	-	-	-
11	15	M	Iliac bone	1	0	-	-	-	-
12	49	M	Iliac bone	2	0	+	-	67.5	73.7
13	38	M	Iliac bone	0	0	-	-	92.1	94.6
14	67	F	Iliac bone	2	-	+	-	-	-
15	63	F	Titan mesh	-	-				

M, male; F, female; post-op, postoperatively; pre-op, preoperatively

Figure Captions

Figure 1. Operating method.

(A) Thermoplastic material is molded to conform to the shape of the orbit on the 3D model. (B) The form of the intended implant material is simulated using a thermoplastic material. (C) The reconstruction material is implanted into the orbital bone defect using plastic as a rigid carrier.

Figure 2. Hess area ratio (HAR%)

The chart on the left (left eye) depicts the affected side, and the right (right eye) depicts the healthy side. HAR% is calculated using the following equation; $(A \times B)/(A' \times B') \times 100$ (%).

Figure 3. Patient 1

The upper images are the frontal photographs of the patient, while the lower images show the coronal section of the computed tomography. In each case, the image on the left is the preoperative image, while that on the right is the postoperative image.

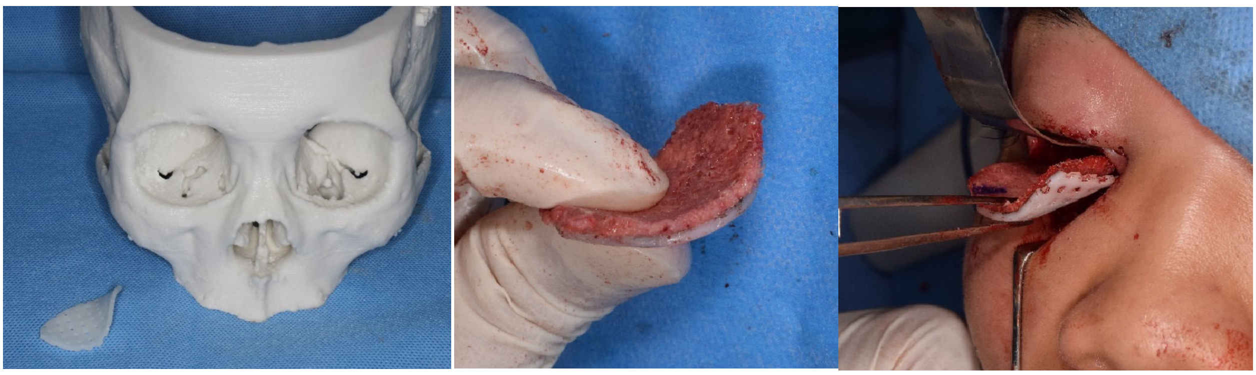
Figure 4. Patient 2

The upper images are the frontal photographs of the patient, while the lower images show the coronal section of the computed tomography. In each case, the image on the left is the preoperative image, while that on the right is the postoperative image.

Figure 5. Patient 3

The upper images are the frontal photographs of the patient, while the lower images show the coronal section of the computed tomography. In each case, the image on the left is the preoperative image, while that on the right is the postoperative image.

Figure 1



A B C

Figure 2

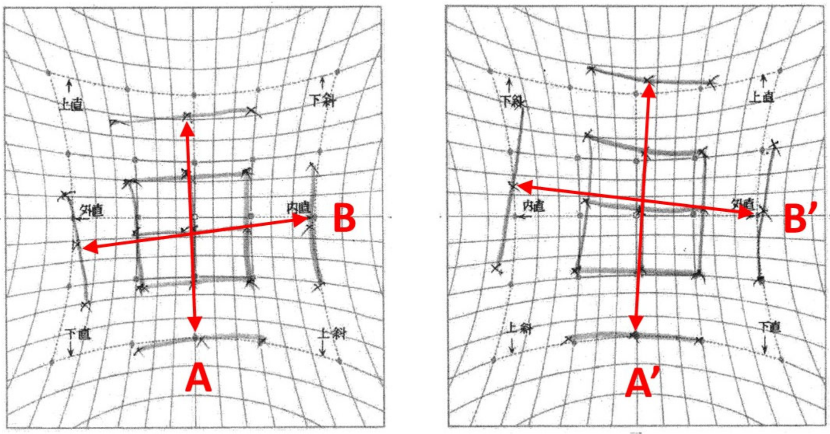


Figure 3

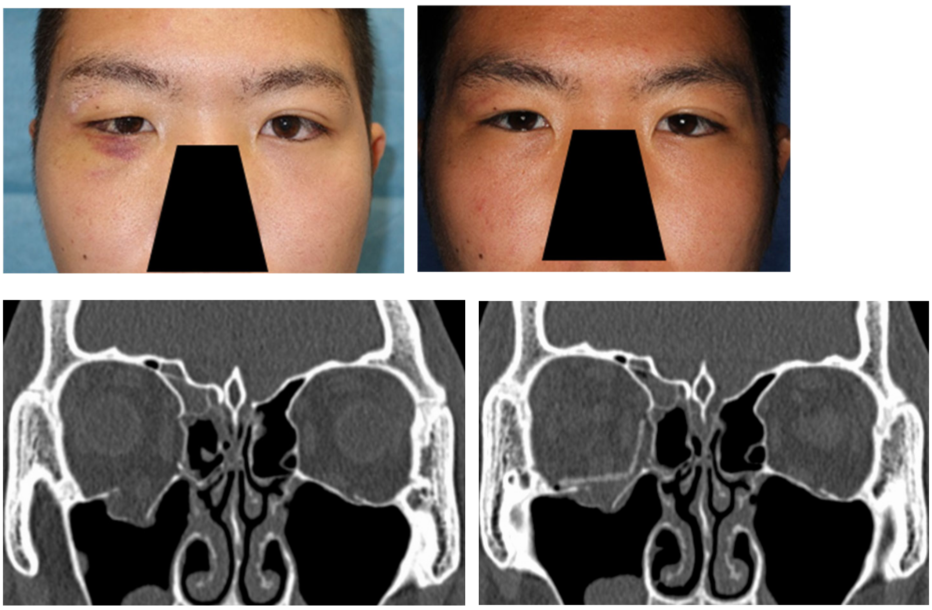


Figure 4

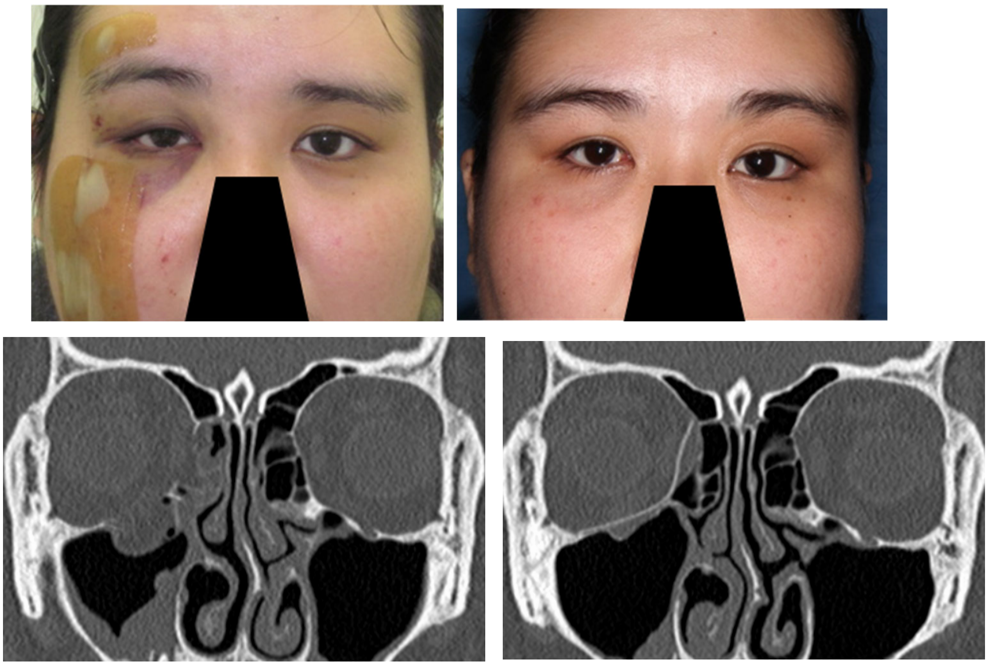


Figure 5