Egypt, J. Plast. Reconstr. Surg., Vol. 49, No. 3, July: 197-204, 2025

Orbital Floor Reconstruction Using A Three-Dimensional Printing Technology in Delayed Cases

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Abstract

Aim: Orbital floor fractures are one of the most common maxillofacial fractures. They account for 10-25% of the total facial bone fractures. Delayed cases are considered challenges in orbital floor fractures. The main obstacle is the difficulty of intraoperative assessment of the fracture defect size because of fibrous adhesions at the site of fractures. This may raise the risk of tissue injury and complications. In this study, we investigated the use of Three-dimensional printing (3DP) technology in the delayed cases of orbital floor fractures for proper preoperative assessment of fracture size and minimize postoperative complications.

Patients and Methods: This prospective study was conducted on 17 cases with delayed orbital floor fractures. All cases were delayed by more than one month, the authors applied the three-dimensional technique for all cases.

Results: The study included 17 cases, 15 males and 2 females. The mean age of the included cases was 25.8±7.3 SD years old. The average delay duration was 5.5±3.7 SD months. Concha graft was used in 11 cases while 6 cases were managed by titanium mesh. Enophthalmos was improved in 13 cases postoperatively. Diplopia was improved in all operated cases.

Conclusion: Using a three-dimensional rapid prototype skull module aid in the accurate preoperative assessment of orbital floor defects and contouring of titanium mesh and plates used in orbital fracture repair. Additionally, this shortens the duration of the operation, uses less general anesthetic, and involves less tissue handling and dissection during the procedure, all of which lead to fewer complications after the procedure.

Key Words: *Diplopia – Enophthalmos – Inferior orbital wall – Orbital fractures – Three-dimensional printing.*

Ethical Committee: The Mansoura Faculty of Medicine's Institutional Review Board (IRB) ethical committee gave its approval to the study (R.23.05.2179. R1).

Conflict of Interest: No conflict of interest.

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Introduction

Orbital floor fractures are one of the most common maxillofacial fractures. Ten to twenty-five percent of all facial bone fractures are caused by them, and up to 70% of orbital fractures are linked to eye globe injury [1]. The most frequent causes of orbital floor fractures, particularly in young people in their second decade of life, include assault, sports, and traffic accidents [2].

Orbital floor fractures can be categorized as pure or impure blowout fractures; pure fractures are isolated orbital floor fractures, while impure are also accompanied by orbital rim fractures involving other adjacent bones (maxillary, zygomatic, naso-ethmoidal, or frontal) [3].

Significant complications are common with these fractures including diplopia, enophthalmos, infraorbital paresthesia, and even blindness. Cases with considerable enophthalmos of more than 2ml and/or diplopia usually need surgical repair of the orbital floor defect [4]. The main problem in delayed cases is the difficulty of repair. Most of them have a degree of bone healing and fibrous adhesions at the site of fractures with no improvement of complications such as diplopia, enophthalmos, and/or infraorbital paresthesia. So, in such cases surgical repair is usually difficult and consumes a prolonged duration of time [5].

Rapid prototyping, another name for three-dimensional printing (3DP) technology, has been used extensively in many medical specialties, particularly in plastic, reconstructive, and craniofacial surgery. Additionally, limb deformity repairs, microtia reconstructions, and free fibula mandibular reconstructions all employ 3D printing. This new method is commonly used because it is much less expensive, more accessible, and takes less time [6].

In orbital floor reconstruction, (3DP) modules help in proper preoperative assessment of fracture defect size and determine the proper size and shape of reconstructive materials, leading to short operation time as there is no need for repeated trimming and molding of a reconstructive material for more precise placement. Also, it decreases soft tissue handling and lessens the formation of orbital edema [7].

Other benefits of (3DP) modules, they help in preoperative patient education and communication between the patient and his surgeon to discuss the anatomy of the orbital floor, size of the defect, type of surgical reconstruction materials, and postoperative results and complications [8]. In this study, the authors investigated the use of three-dimensional printing (3DP) technology in delayed cases of orbital floor fractures for proper preoperative assessment of fracture size and to minimize postoperative complications.

Patients and Methods

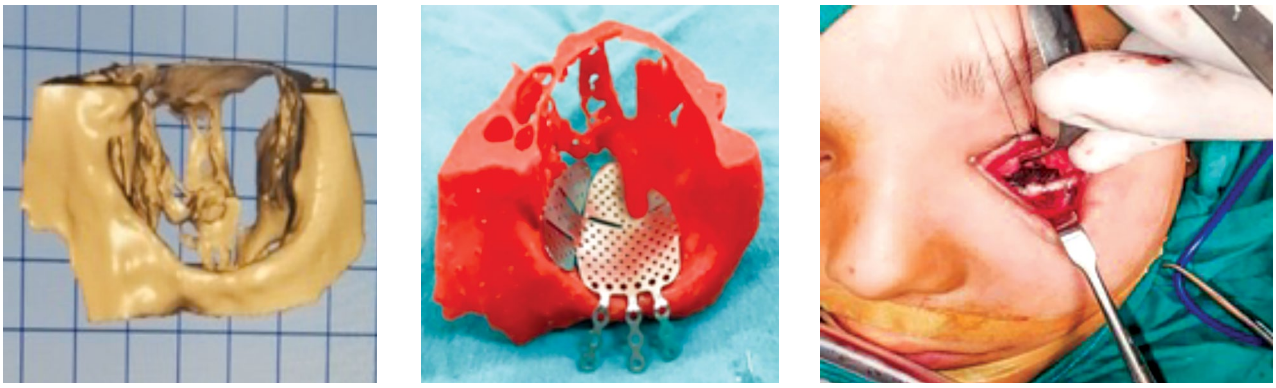
Seventeen patients with delayed orbital floor fractures were included in our study. All patients underwent treatment at the Department of Plastic & Reconstructive Surgery, Mansoura University between January 2020 and January 2022.

The patients' gender, age, mechanism of trauma, fracture size, orbital soft tissue herniation volume, preoperative symptoms, surgical intervention timing, surgical approaches, reconstruction materials, operation length, and postoperative problems were all examined. The clinical presentation was combined with computed tomography (CT) images of the orbit in axial, coronal, and three-dimensional (3D) perspectives to make the final diagnosis. All patients were ophthalmologically assessed on the day of admission, preoperatively and postoperatively.

Clinical indications for surgery include diplopia, enophthalmos, and ocular motility problems, radiological indications include infraorbital bony stepping, and size of the defect more than $2cm^2$ with orbital soft tissue herniation volume of more than 1ml 3 in the CT scan. Proper history taking should include age, gender, time and mode of trauma, past orbital surgeries, and other medical and surgical histories. Upon examination, 14 patients had diplopia, 15 had enophthalmos, and 5 had infraorbital paresthesia.

Computer tomography scan (CT) was done in axial, coronal, and 3D views for all patients. It revealed the site, size, shape of the defect, and volume of orbital soft tissue herniation.

CT scans were acquired with a layer thickness of 0.05mm and a region of interest (ROI) resolution of 512×512, which corresponds to a voxel size of 0.331×0.331×0.5 mm, according to digital imaging and communications in medicine (DICOM) data. Hounsfield unit thresholding was used to segment the skull from DICOM volumetric data using 3D slicer software (version 4.62, http://www.slicer.org). Meshmixer, a 3D modeling program (version 3.2, Autodesk, CA, USA), was used to enhance a 3D skull model that had been first designed in standard triangle language (STL) format (Fig. 1). The skull was trimmed to exclude the orbital floor abnormality. All models were made using 0.178 mm-thick layers of medically engineered acrylonitrile butadiene styrene, which was sterilized using low-temperature hydrogen peroxide gas plasma.



(A) (B) (C)

Fig. (1): (A) 3D printing module (STL) file during preparation before printing. (B) 3D printed model with titanium mesh molded to fit the size and shape of fracture. (C) Intraoperative view showing reconstruction of orbital floor fracture with the previously molded titanium mesh.

All operations were done under general anesthesia. Nine patients were operated on through a subciliary incision, five patients through a transconjunctival incision, and three patients through an existing wound incision. This study utilized conchal cartilage graft and titanium mesh for orbital floor repair. Conchal cartilage was utilized for smaller defects, while titanium mesh was utilized for larger orbital floor deformities that accounted for over 50% of the orbital floor size. These reconstructive materials were trimmed and molded to fit the size and shape of the orbital floor defect according to the 3D printed module, so it helped in the direct insertion of reconstructive materials with no need for reassessment of orbital floor defect size intraoperatively which by its role shortened operation time (Figs. 2,3). Before wound closure, forced duction tests were used to ensure no longer entrapment of orbital muscles through the orbital defect.

Postoperatively, visual acuity and ocular motility were assessed in all cases. Medical treatment was prescribed as topical antibiotics eye drops, anti-edematous drugs, and analgesics till postoperative edema subsided through 3-5 days. Postoperative CT was performed immediately following surgery and after 6 months of follow-up.

Fig. (2): Male patient 25 years with a history of road traffic accident associated with left orbital floor fracture, inferior orbital wall, and lateral orbital wall, The patient was admitted 8 months after trauma complaining of enophthalmos and diplopia in upward gaze direction. (A,B) Preoperative inferior and anterior clinical views of the patient showing enophthalmos of the left eye (CP: Corneal plane, MP: Maxillary plane, FP: Frontal plane). (C) CT scan, coronal view showing fracture of left orbital floor, inferior orbital wall, and lateral orbital wall with soft tissue herniation. (D) 3D printed model with titanium mesh molded to fit the size and shape of the fracture. (E) Intraoperative clinical view with the previously molded titanium mesh. (F,G) Immediately postoperative CT coronal and sagittal views respectively showing reconstruction of the left orbital floor with titanium mesh without herniation of orbital soft tissue. (H,I) Anterior and inferior clinical views respectively after 6 months showing resolved enophthalmos and patient no longer complains of diplopia.

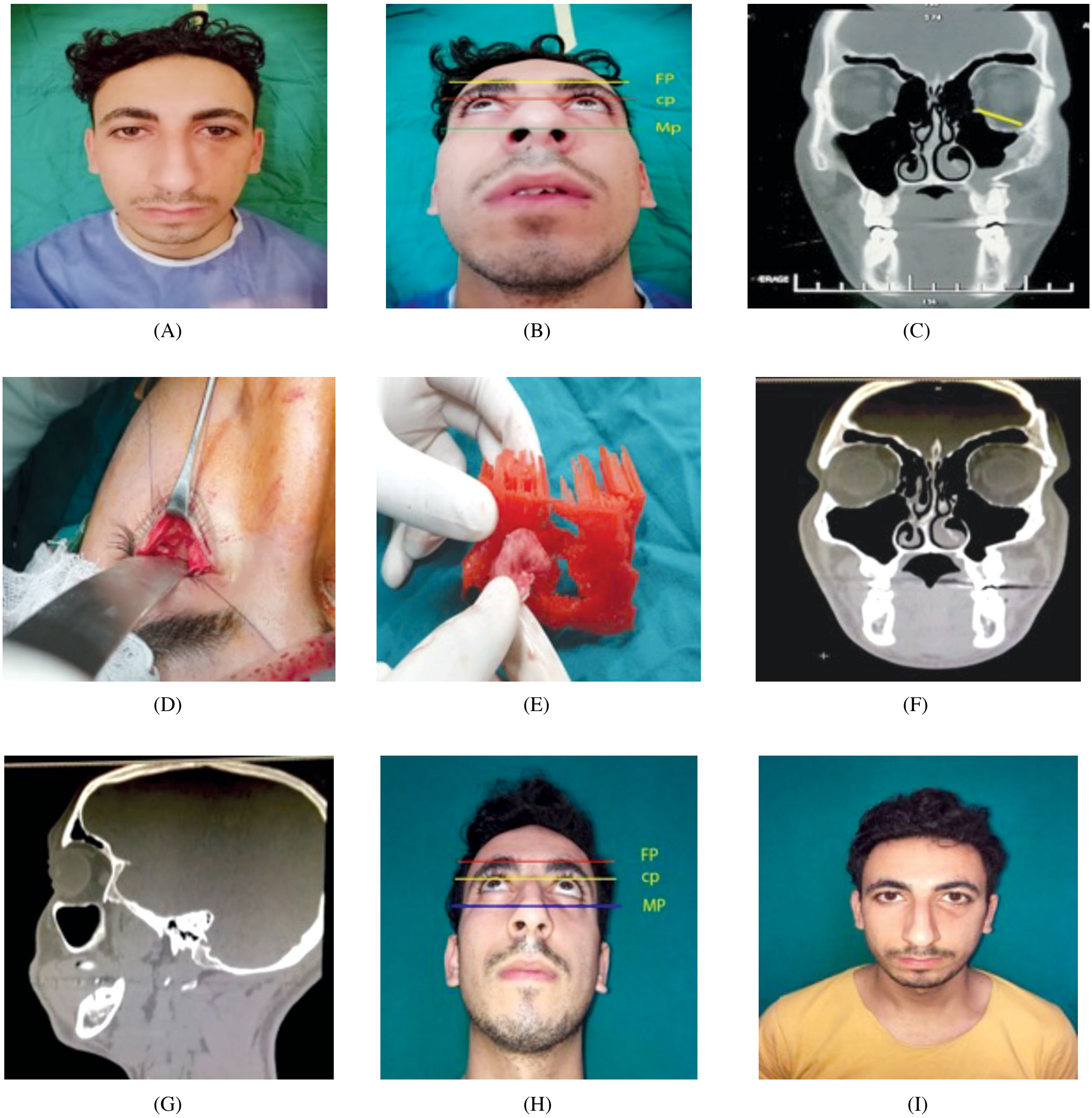


Fig. (3): Male patient 22 years old with a history of road traffic accident associated with left orbital floor fracture, inferior orbital wall, and lateral orbital wall delayed one month. The patient was admitted to our center one month after trauma complaining of diplopia in an upward gaze direction. A 3D module was printed, and reconstruction was done by conchal cartilage graft. (A,B) Preoperative anterior and inferior clinical views of the patient showing no enophthalmos of the left eye (CP: Corneal plane, MP: Maxillary plane, FP: Frontal plane). (C) Coronal CT radiological showing fracture of left orbital floor and lateral orbital wall with soft tissue herniation. D) Intraoperative clinical view showing left orbital floor fracture. (E) 3D printed model with conchal cartilage graft molded to fit the size and shape of fracture. (F,G) Postoperative CT coronal and sagittal views respectively showing repair of the left orbital floor without herniation of orbital soft tissue. (H,I) Anterior and inferior clinical views respectively after 6 months.

Results

The study included 17 cases. Males accounted for 88.2% of cases (n=15), while females accounted for 11.8% (n=2) (Table 1). The mean age of the included cases was 25.82 years old (minimum 10, maximum 36). The peak incidence emerges in the 2nd decade of life.

Six cases had orbital floor fractures in their right eye, while eleven patients complained of orbital floor fractures in their left eye. Road traffic accidents (RTA) (vehicle and motorbike) were the leading cause of orbital floor fractures in our study, accounting for 76.4% (13/17) of all cases. Violence accounted for 23.7% (4/17) of the patients.

The average time from trauma to surgical repair was 5.58 months (minimum 1 month and maximum 13 months). 64.7% (11 patients) of orbital floor defects were repaired using a conchal graft, while 35.3% (6 patients) were treated with titanium mesh.

Enophthalmos was the most common sign (88.23%). It was a complaint in 15 patients. It improved in 13 patients postoperatively while 2 patients still complained. Fourteen patients (82.3%) complained of diplopia but postoperatively diplopia improved in all operated cases (Table 2). The third common complaint was infraorbital paresthesia (hypoesthesia, anesthesia, or numbness) in 5 patients (29.4%). Postoperatively, one patient complained of paresthesia while the other 4 patients improved.

The average fracture size on the orbital floor was $2.35cm^2$ (minimum $1cm^2$, maximum $4cm^2$). Orbital soft tissue herniation volume ranged from 1 to $2.3ml^3$, averaging $1.47ml^3$ (Table 1).

Three types of surgical incisions were used. Five patients (29.41%) underwent trans-conjunctival incision, while nine patients (52.94%) underwent subciliary incision, whereas three individuals (17.65%) used an existing wound incision.

The operative duration ranged from 52 minutes to 88 minutes (median 68.5 minutes). On reviewing the 15 consecutive orbital floor reconstructions with implants in our center without using 3DP, with 3DP, the operation time was shortened by almost 30 minutes because the range of the operative time was 68 to 125 minutes (median 96.5 minutes) (Table 1).

Table (1): Preoperative and postoperative patients' data.

Case number	Sex	Age in years	Chronicity period in months	Mode of trauma	Side of fracture	Defect size in cm^2	Herniation volume in ml^3	Material used	Incision	Duration of surgery in minutes
1	Male	10	12	RTA	Left	4	2.3	Mesh	Subciliary	56
2	Female	21	5	RTA	Right	2	1.5	Graft	Subciliary	66
3	Male	25	8	RTA	Left	3	1.6	Mesh	Subciliary	52
4	Male	22	1	RTA	Left	2	1.3	Graft	Existing wound incision	76
5	Male	18	3	RTA	Left	3	1.5	Mesh	Transconjunctival	88
6	Male	32	2	Violence	Right	1	1.2	Graft	Transconjunctival	69
7	Male	16	5	Violence	Left	1	1.1	Graft	Subciliary	68
8	Male	36	8	RTA	Right	2	1	Graft	Subciliary	63
9	Male	30	6	RTA	Right	4	2.1	Mesh	Subciliary	78
10	Female	26	10	RTA	Left	2	1.2	Graft	Transconjunctival	77
11	Male	28	13	RTA	Left	3	1.6	Graft	Subciliary	74
12	Male	20	1	RTA	Left	4	1.9	Mesh	Existing wound incision	59
13	Male	30	5	RTA	Right	1	1.5	Graft	Subciliary	58
14	Male	35	2	RTA	Left	2	1.3	Graft	Subciliary	65
15	Male	36	6	RTA	Left	1	1.1	Graft	Transconjunctival	69
16	Male	26	7	Violence	Left	3	1.6	Mesh	Transconjunctival	68
17	Male	28	1	Violence	Right	2	1.2	Graft	Existing wound incision	78

Table (2): Preoperative and postoperative clinical symptoms and signs.

Preoperative symptoms and signs	Postoperative symptoms and signs (after 6 months)	
Diplopia (n=14)	Improved (n=14)	Not improved (n=0)
Enophthalmos (n=15)	Improved (n=13)	Not improved (n=2)
Infraorbital paresthesia (n=5)	Improved (n=4)	Not improved (n=1)

N:Number.

Discussion

Orbital trauma is one of the most common maxillofacial fractures of surgical importance because it impairs ocular mobility and visual acuity **[9]**. Restoring the orbit's original volume and form, repositioning its contents, and regaining ocular mobility are the goals of managing the orbital floor fracture **[10,11]**.

Surgical treatment of orbital floor fractures should be performed without delay to avoid complications such as diplopia, enophthalmos, inappropriate fracture healing, and dystopia [12]. Causes of delay may be unfit patients for general anesthesia or patients refusing surgery at the time of trauma Since swelling frequently conceals enophthalmos so many cases may be delayed for weeks or months. This was in line with a study that reported a retrospective examination of 46 patients by Wenjuan Lu et al. At an average of 5.3 months after Orbital-Zygomatic-Maxillary injury; the main causes of delay were because little is known about the significance or limitations of the condition in various health centers, also Orbital-Zygomatic-Maxillary fractures are often linked to injuries to the brain, heart, or other important organs that need immediate treatment to stabilize vital signs [13].

There are numerous uses for three-dimensional technologies in the medical industry. In plastic reconstructive surgery, 3DP-driven surgical applications are becoming more widespread [14]. Utilizing 3D printing to restore orbital fractures may enhance the result and optimize the functional and aesthetic restoration of the traumatized orbits [15].

Seventeen patients were included in our study. All patients were delayed from one month to 13 months. All cases were complaining of unilateral orbital floor fractures, with 11 patients with left orbital floor fractures and 6 patients with right orbital floor fractures. All cases were managed using the STL model 3D printed.

Fifteen cases were males while females represented two cases, this is explained by the fact that men constitute the main working force in our society with increased violence rates between males than females. This supports the statistics of Gosau that reported one hundred forty-eight (78.3%) men, and 41 (21.7%) women were recorded; thus, the gender distribution was 3.6:1 [16].

The cases' average age ranged from 10 to 36 years old, with a mean of 25.82 years, and incidence peaks in the second decade. Car and motorbike road traffic accidents (RTAs) accounted for 76.4% (13/17) of all instances. Unlike the Venugopal study, violent attack was the primary cause of orbital floor fractures (29.6%), followed by traffic accidents (25.1%) [17].

Diplopia was present in 14 cases and resolved in all cases postoperatively within 3 months. Five patients only complained of infraorbital paresthesia. Four improved while one patient complained of numbness in the infraorbital region (Table 2). This high improvement rate was due to proper preoperative assessment of fracture size and soft tissue herniation volume by CT radiology and remodeling of 3D models according to CT dimensions. These findings were consistent with research by Farag Allah et al., that concluded that 60% of cases (3 patients from each group). After one week of surgical intervention, diplopia was present in 50% of cases, all patients' diplopia had disappeared a month after surgery [18]. Hosşal et al., agreed that surgically repairing blowout fractures within two weeks of trauma can reduce the incidence of persistent diplopia. That diplopia improves from a few weeks to months after surgery [19].

The most concerning consequence after orbital wall fractures and OZM fractures is enophthalmos [20]. The most prevalent cause of enophthalmos is an increase in the size of the bony orbit due to orbital wall defects or the displacement of shattered segments [21]. The herniated orbital tissue may fall into the maxillary or ethmoidal sinuses or become lodged in the broken crack. Fan et al., determined orbital volume using computer-aided 3D orbital measurements and verified the linear relationship between orbital volume increment and enophthalmos degree so the quantity of implanted materials needed for the procedure can be estimated from the difference between the preoperative orbital volumes of the affected and unaffected sides [22].

Fifteen cases were complaining of enophthalmos. It was improved in 13 patients. Only two patients managed with conchal cartilage graft still complained of enophthalmos. After 6 months they had revision surgery and surgically repaired by titanium meshes. Enophthalmos had been improved, according to Kozakiewicz, M. and his group, since the pre-shaped orbital floor implants had a more precise "true-to original" shape that more closely matched the original shape of the broken bone [23].

Cases with defect sizes of more than 2.5cm^2 were managed by titanium mesh or double conchal cartilage. Conchal cartilage transplants were used to treat cases with orbital floor abnormalities smaller than 2.5cm^2 . This was supported by Potter et al. study. They preferred the usage of titanium mesh as they are available, biocompatible, easy intraoperative contouring, and rigid fixation [24].

Applying 3D printing assists in determining the appropriate size and form of reconstructive materials. Fibrosis and challenging dissection surrounding the important components posed the most obstacle in delayed cases, three-dimensional printing's primary purpose was not to aid in the molding of artificial material used for reconstruction but rather than the precise preoperative evaluation of fracture defect size and form and choosing the proper reconstructive material size and form. The current study did not include reconstruction of the orbital floor using bone graft and it was supported by Chang et al., study due to bone graft complications such as cranial encephalitis or iliac bone osteomyelitis according to donor site used for bone graft also difficult remodeling of bone graft according to orbital floor defect [25]. To fix the volumetric expansion and seal the orbital wall flaw, materials like HDPE and titanium mesh were employed. In certain instances, orbital wall fractures could be treated without the need for implant fixation. In addition, Nam et al. [21] implanted porous polyethylene or hydroxyapatite in 405 individuals without fixation and observed no bleeding, migration, or extrusion.

Authors preferred subciliary incision over transconjunctival in most cases as it provided us with better visualization of the surgical field, especially in cases with orbital floor fractures associated with other zygomaticomaxillary fractures while Lim and his team preferred transconjunctival incision in their study as it is more cosmetic [26].

The three-dimensional implant had a great benefit in shortening the time of surgery. The average time of our seventeen surgeries was 68.47 minutes which is shorter than the average time of previous surgeries without 3DP modules by nearly 30 minutes. This was in accordance with research by Weadock et al., that found that, prior to the use of 3D-printed molds, the average surgical duration was 93.3 minutes. With a range of 36 to 57 minutes, the average surgical time is 48.3 minutes [27].

Conclusion:

Based on the study's findings, it is possible to conclude that using a three-dimensional rapid prototype skull module aid in the accurate preoperative assessment of orbital floor defects. Additionally, this shortens the duration of the operation, uses less general anesthetic, and involves less tissue handling and dissection during the procedure, all of which lead to fewer complications after the procedure.

Acknowledgment: We would like to thank the scientific research office at the Mansoura Faculty of Medicine for statistical analysis.

References

1- Nagase D.Y., Courtemanche D.J. and Peters D.A.: Facial fractures–association with ocular injuries: A 13-year review of one practice in a tertiary care center. Canadian Journal of Plastic Surgery, 14 (3): 167-171, 2006.

2- Chi M.J., Ku M., Shin K.H. and Baek S.: An analysis of 733 surgically treated blowout fractures. Ophthalmologica, 224 (3): 167-175, 2010.

3- Bartoli D., Fadda M.T., Battisti A., Cassoni A., Pagnoni M., Riccardi E. and Valentini V.: Retrospective analysis of 301 patients with orbital floor fracture. Journal of Cranio-Maxillofacial Surgery, 43 (2): 244-247, 2015.

4- Safi A.F., Richter M.T., Rothamel D., Nickenig H.J., Scheer M., Zöller J. and Kreppel M.: Influence of the volume of soft tissue herniation on clinical symptoms of patients with orbital floor fractures. Journal of Cranio-Maxillofacial Surgery, 44 (12): 1929-1934, 2016.

5- Hartstein M.E. and Roper-Hall G.: Update on orbital floor fractures: Indications and timing for repair. Facial plastic surgery, 16 (02): 095-106, 2000.

6- Pang S.S.Y., Fang C. and Chan J.Y.W.: Application of three-dimensional printing technology in orbital floor fracture reconstruction. Trauma Case Reports, 17: 23-28, 2018.

7- Prabhu S.S., Chung S.A., Brown P.J. and Runyan C.M.: Utilizing 3D-printed orbital floor stamps to create patient-specific implants for orbital floor reconstruction. Ophthalmic Plastic & Reconstructive Surgery, 37 (1): 81-85, 2020.

8- Ganguli A., Pagan-Diaz G.J., Grant L., Cvetkovic C., Bramlet M., Vozenilek J. and Bashir R.: 3D printing for preoperative planning and surgical training: A review. Biomedical microdevices, 20 (3): 65, 2018.

9- Ellis E.: Orbital trauma. Oral and Maxillofacial Surgery Clinics, 24 (4): 629-648, 2012.

10- Burnstine M.A.: Clinical recommendations for repair of isolated orbital floor fractures: An evidence-based analysis. Ophthalmology, 109 (7): 1207-1210, 2002.

11- Hossam Elgayar, Omar Osama Shouman, Mostafa M. Abdelhalim, Ashraf Abass and Ahmed M. Zeina: Retrospective Analysis of the Outcomes in Orbital Floor Fractures: Guidelines for Better Strategic Management. J. Plast. Reconstr. Surg., Vol. 45, No. 1, January: 49-58, 2021.

12- Lee J., Tahiri Y., Roy A.A. and Lessard L.: Delayed repair of lateral orbital wall and orbital floor fracture. J. Craniofacial Surg., 24 (1): 34-7, 2013.

13- Lu W., Zhou H., Xiao C., Shen Q., Lin M. and Fan X.: Late correction of orbital-zygomatic-maxillary fractures combined with orbital wall fractures. Journal of Craniofacial Surgery, 23 (6): 1672-1676, 2012.

14- Yao R., Xu G., Mao S.S., Yang H.Y., Sang X.T., Sun W. and Mao Y.L.: Three-dimensional printing: Review of application in medicine and hepatic surgery. Cancer biology & medicine, 13 (4): 443, 2016.

15- Park S.W., Choi J.W., Koh K.S. and Oh T.S.: Mirror-imaged rapid prototype skull model and pre-molded synthetic scaffold to achieve optimal orbital cavity reconstruction. Journal of Oral and Maxillofacial Surgery, 73 (8): 1540-1553, 2015.

16- Gosau M., Schöneich M., Draenert F.G., Ettl T., Driemel O. and Reichert T.E.: Retrospective analysis of orbital floor fractures complications, outcome, and review of literature. Clinical oral investigations, 15 (3): 305-313, 2011.

17- Venugopal M.G., Sinha R., Menon P.S., Chattopadhyay P.K. and Chowdhury S.R.: Fractures in the maxillofacial region: A four-year retrospective study. Medical Journal Armed Forces India, 66 (1): 14-17, 2010.

18- Farag Allah S.S.E.N., Abdallah M.A. and Almohandis W.A.A.: Reconstruction of Orbital Fracture with the Aid of Mirror Imaged 3D Printed Models. The Egyptian Journal of Hospital Medicine, 78 (2): 286-293, 2020.

19- Hossal B.M. and Beatty R.L.: Diplopia and enophthalmos after surgical repair of blowout fracture. Orbit, 21 (1): 27-33, 2002.

20- He D., Li Z., Shi W., Sun Y., Zhu H., Lin M., Shen G. and Fan X.: Orbitozygomatic fractures with enophthalmos: Analysis of 64 cases treated late. J. Oral Maxillofac Surg., 70 (3): 562-76, 2012.

21- Nam S.B., Bae Y.C., Moon J.S., et al.: Analysis of the postoperative outcome in 405 cases of orbital fracture using 2 synthetic orbital implants. Ann. Plast. Surg., 56: 263-267, 2006.

22- Fan X., Li J, Zhu J., et al.: Computer-assisted orbital volume measurement in the surgical correction of late enophthalmos caused by blowout fractures. Ophthalmol. Plast. Reconstr. Surg., 19: 207-211, 2003.

23- Kozakiewicz M., Elgalal M., Loba P., Komuńsk P., Arkuszewski P., Broniarczyk-Loba A. and Stefańczyk L.: Clinical application of 3D pre-bent titanium implants for orbital floor fractures. Journal of Cranio-Maxillofacial Surgery, 37 (4): 229-234, 2009.

24- Potter J.K. and Ellis E.: Biomaterials for reconstruction of the internal orbit. Journal of oral and maxillofacial surgery, 62 (10): 1280-1297, 2004.

25- Chang E.L. and Bernardino C.R.: Update on orbital trauma. Current opinion in ophthalmology, 15 (5): 411-415, 2004.

26- Lim C.G., Campbell D.I. and Clucas D.M.: Rapid prototyping technology in orbital floor reconstruction: Application in three patients. Craniomaxillofacial trauma & reconstruction, 7 (2): 143-146, 2014.

27- Weadock W.J., Heisel C.J., Kahana A. and Kim J.: Use of 3D printed models to create molds for shaping implants for surgical repair of orbital fractures. Academic Radiology, 27 (4): 536-542, 2020.