Evaluation of Orbital Volume Correction in Stereolithographic models using Addition Silicone Impression Material: A Prospective Study

Neha Umakant Chodankar[1], Vikas Dhupar[2], Vathsalya Vijay[3], Rakshit Khandeparker[4]

ABSTRACT

Objectives: The purpose of this study was to evaluate orbital volume correction in blowout fractures by comparing volumes of addition silicone impressions of uninjured side, fractured and reconstructed orbits of stereolithographic (STL) models followed by comparison of the same with volumes obtained by manual segmentation technique using computed tomography software.

Material and Methods: This prospective study was conducted on a group of 7 cases of operated impure orbital blowout fractures. STL models of preoperative and postoperative scans were printed and addition silicone putty impressions were taken of the uninjured, fractured and reconstructed orbits. Orbital volumes were estimated byi)measuring volume of material used to make impression, ii)water displacement method and iii)using CT software techniques. The preoperative, uninjured side and postoperative volumes estimated with all three techniques were compared. Statistical analysis was done using repeated measure ANOVA and paired t test.

Results: Values obtained by all three techniques were similar. Comparison of postoperative orbital volumes with that of uninjured side in all techniques was found to be statistically significant($p=0.02$). The comparison of postoperative and uninjured side volumes in water displacement method had statistically significant difference($p=0.002$). Comparison of preoperative and postoperative volumes within each technique revealed statistically significant difference between the same in all three methods while that of water displacement method was highly significant($p= 0.009$).

Conclusions: The technique of orbital volume estimation using addition silicon impression material is simple, easily reproducible, does not require technical expertise and allows for volume estimation which can be closely matched with that of software manual segmentation technique.

Keywords: orbit fractures, Printing, Three-Dimensional, stereolithographic models, stereolithographic models, orbital reconstruction, silicone impression material

---

INTRODUCTION

The management of orbital fractures is one of the most challenging aspects of facial trauma. The complex three dimensional configuration of the orbital walls in combination with a weak bony framework and close proximity to vital structures makes anatomic reconstruction an extremely daunting task, more so in two wall fractures and when the deep orbital cone is affected[1]. Hence thorough surgical planning is imperative. The primary goal of orbital reconstruction is restoration of the orbital hard tissues to its pre-injury anatomy and to restore orbital volume by bridging the bony defect using suitable reconstructive implants in addition to restoration of facial fractures by internal fixation[1,2]. Thus meticulous assessment of orbital volume is fundamental to obtain good functional as well as aesthetic results in orbital reconstruction surgery[3].

Numerous methods have been described in literature for analysis of the orbital volume, the gold standard technique being manual segmentation using different software. However, this technique is expensive, requires an understanding of the software and can lead to operator bias[3,4]. Literature also describes the use of dental impression materials like addition silicones for orbital volume assessment. Unlike manual segmentation, this option is easy to use, is reproducible, fast, economical and does not require technical expertise to master. However, all of the studies using impression materials have been carried out on cadavers and have not been implemented on STL models as of now[3]. Also, no cadaveric studies have been found that account for orbital volume assessments in blowout fractures.

The purpose of this study was to evaluate orbital volume correction in blowout fractures by comparing volumes of addition silicone impressions of uninjured side, fractured and reconstructed orbits of Stereolithographic models followed by comparison of the same with volumes obtained by manual segmentation technique using CT software.

MATERIALS AND METHODS

This clinical study was conducted in Goa Dental College & Hospital on a total of 7 patients with impure orbital blowout fractures who were diagnosed with zygomaticomaxillary fractures with orbital blowout fractures. All patients underwent orbital reconstruction using preformed implants (Synthes Matrixmidface Orbital plate, Oberdorf, Switzerland) following open reduction and internal fixation of any associated fractures using miniplates and screws (Orthomax, Gujrat, India). Written informed consent was taken for the same. An institutional review board (IRB) approval was obtained for the study protocol.

In all patients, pre and post operative CT scans were taken with 1mm slice thickness (Figure no 1). These scans were used for fabrication of the STL models both pre and post operatively. Addition silicone putty (Zhermack, Italy) impressions were taken of the fractured orbits of STL models after blocking out the floor of the defect using modeling wax. Impressions of the uninjured contralateral side were also made using the preoperative STL models. Impressions in postoperative models did not require blocking out of defect. The volume of the impression material was measured using measuring scoops of precise volumes (measuring 1cc, 2cc, 5cc, 10 cc and 20cc) prior to insertion into area of interest. On completion of the setting time, the impression material was pulled out gently using a metallic pin. Preoperative, uninjured side and postoperative impressions were compared with regards to its shape, size and volume.

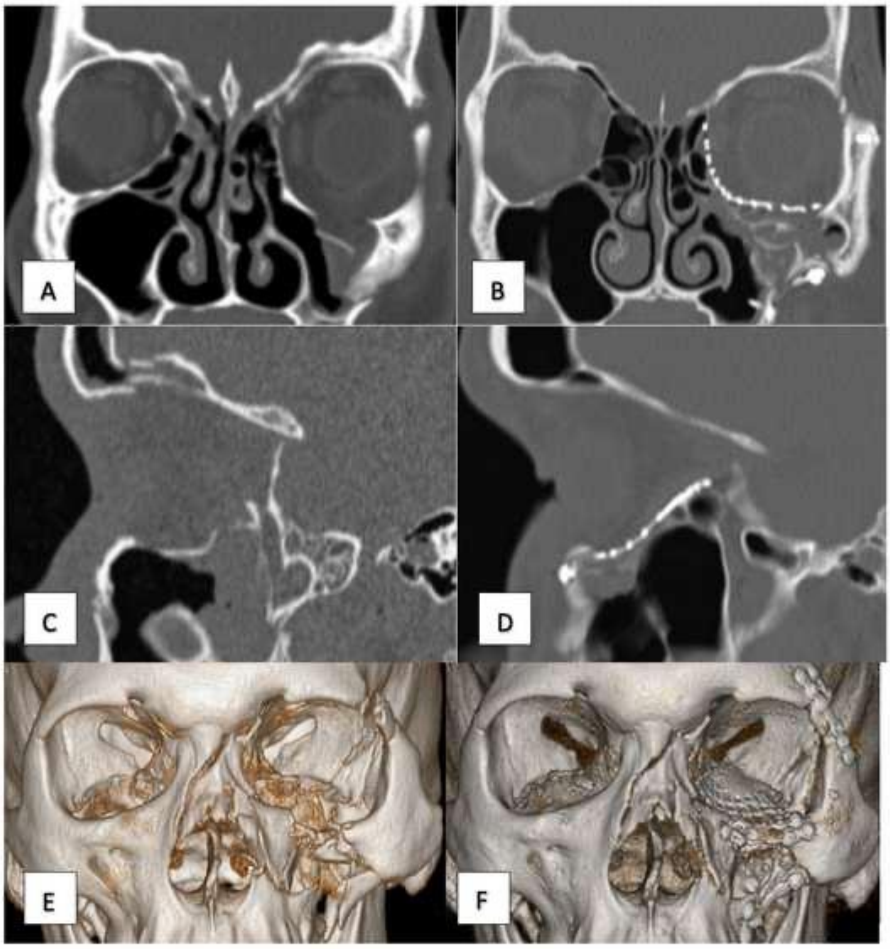

Fig no 1: – Preoperative and postoperative CT images: A, B- Coronal sections, C,D- Sagittal sections and D,E- 3D Reconstructed Images

Volumes of impressions were then also measured using water displacement method. The volumes of the impressions were measured using graduated measuring cylinders filled with 100cc of water by immersing the impressions and noting the change in the level of wateror the volume of water displaced. Lastly, orbital volumes were measured using manual segmentation using OsiriX MD software (FDA approved, USA) by a different observer to avoid bias (Acton Healthcare Engineering and Innovations Pvt Ltd, Virar, Palghar, Maharashtra, India). The volumes estimated with all three techniques were then compared.

Step 1: Preoperative STL models were printed. The defect was outlined and blocked with modeling wax(Figure no 2).

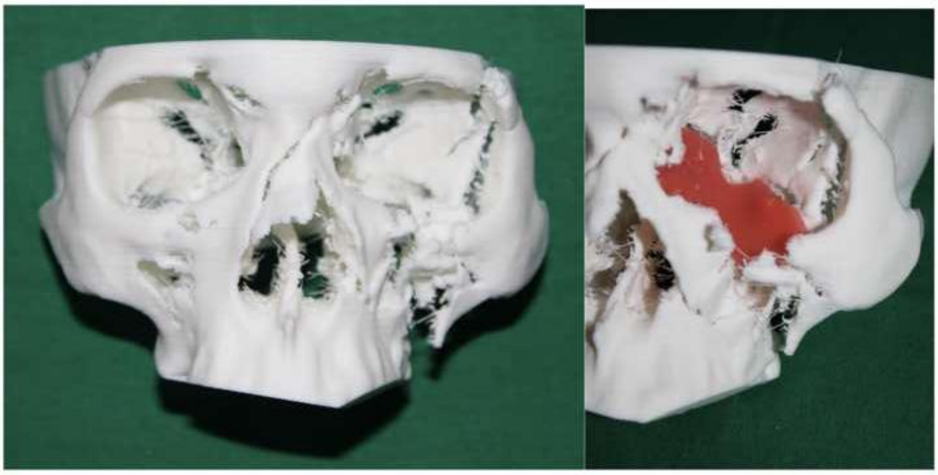

Fig no 2:– Preoperative STL model with blocking out of depth of defect

Step 2: A premeasured amount of addition silicone putty impression material was placed in the fractured orbit using a metallic pin with a stopper of modeling wax to block out the orbital apex (Figure no 3). The impression was taken out after completion of its setting time (Figure no 4). The shapes of the defects could be accurately appreciated in the impression. An impression was also taken of the uninjured side.

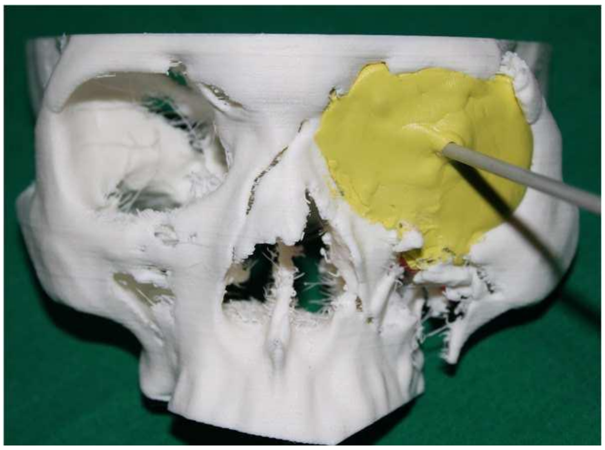

Fig no 3:– Addition silicone impression of fractured orbit

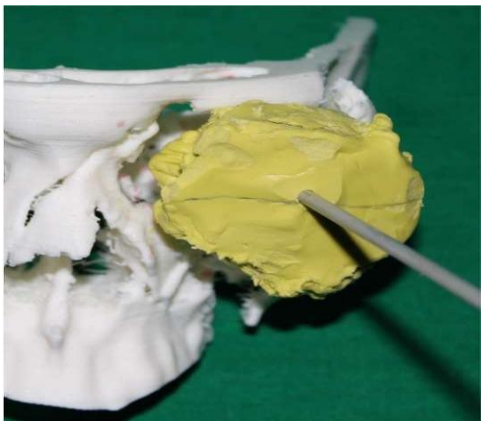

Fig no 4: Removal of Addition silicone impression from fractured orbit

Step 3: The same process as above was carried out using the postoperative model. (Figure no 5,6 and 7) The correction of the defects and the restoration of the approximate shape of the orbit could be appreciated.

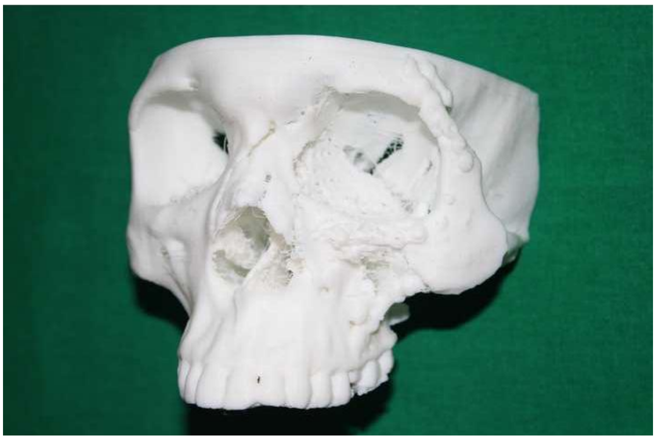

Fig no 5: Postoperative STL model

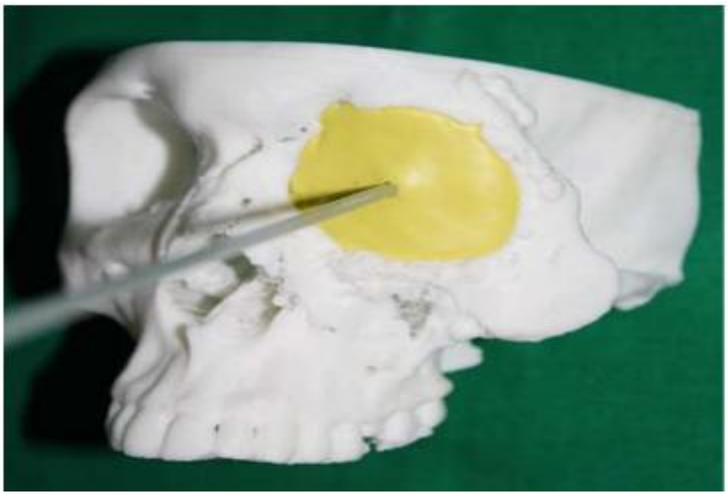

Fig no 6: Impression of postoperative STL model

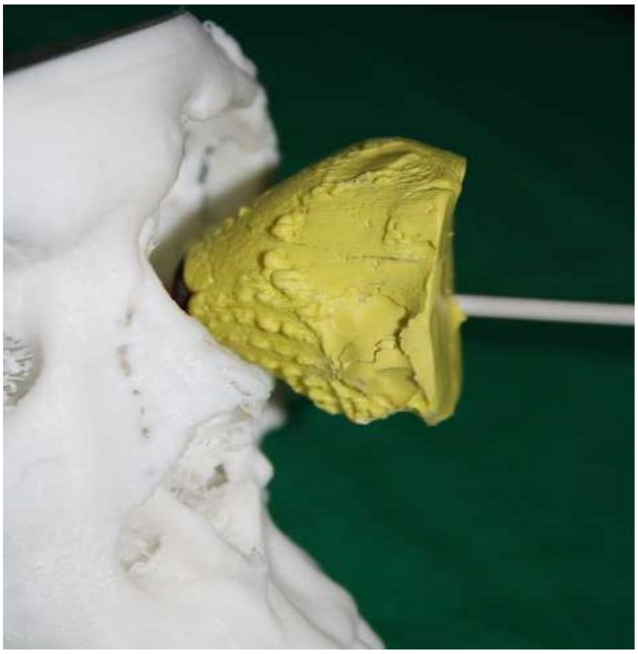

Fig no 7: Removal of impression from reconstructed orbit

Step 4: The preoperative and postoperative impressions were compared. (Figure no 8)

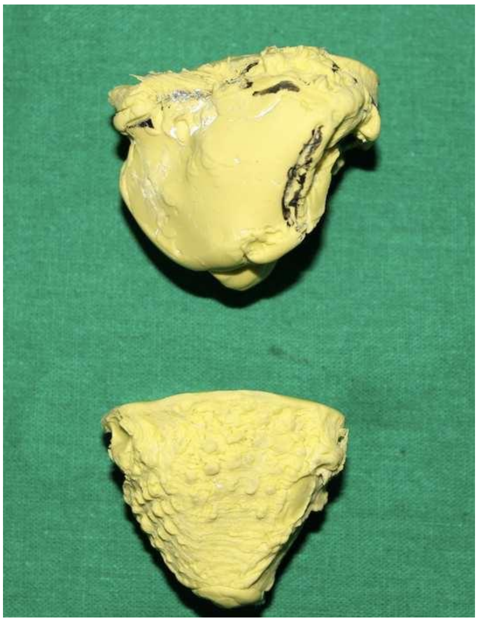

Fig no 8: Comparison of preoperative and postoperative impressions

Statistical analysis

The data obtained was tabulated and subjected to statistical analysis using SPSS Version 22. Postoperative and uninjured side orbital volumes measured using all three techniques were compared using repeated measure ANOVA test. Preoperative and postoperative volumes were compared within individual techniques using Paired t test. A p-value of <0.05 was considered to be statistically significant.

RESULTS

The preoperative, postoperative and uninjured side orbital volumes measured using all three techniques have been presented in Table no 1.

Table no 1: Preoperative, Postoperative and Uninjured side orbital volumes obtained using all three techniques

Case no.	**Orbital Volumes measured using Software Program**			**Orbital Volumes based on volume of impression material used**			**Orbital Volumes measured using water displacement method**		
	Preoperative	Postoperative	Uninjured	Preoperative	Postoperative	Uninjured	Preoperative	Postoperative	Uninjured
1	28.35cc	23.07cc	23.03cc	28cc	22cc	22cc	26cc	20cc	24cc
2	37.8cc	22.89cc	22.84cc	37cc	23cc	22cc	35cc	20cc	25cc
3	34.12cc	23.68cc	23.34cc	33cc	23cc	23cc	28cc	22cc	21cc
4	24.33cc	22.61cc	22.17cc	24cc	22cc	22cc	21cc	19cc	24cc
5	21.04cc	20.3cc	20.19cc	21cc	22cc	21cc	23cc	20cc	23cc
6	26.82cc	23.8cc	23.76cc	26cc	24cc	23cc	24cc	20cc	21cc
7	27.8cc	23.81cc	23.76cc	27cc	23cc	24cc	30cc	20cc	21cc

A marked correction was noted in orbital volumes postoperatively in each group. Values obtained in all techniques more or less correlated with one another. Volume estimation in the CT software group allowed recording of values in decimal points thereby contributing to higher accuracy as compared to other two methods. Volume assessment in the water displacement method was found to be highly arbitrary.

Comparison of the postoperative orbital volumes with that of the uninjured side in all three techniques were found to be statistically significant (p value 0.02) Table 2. Following this a pairwise comparison was done in a post hoc fashion to estimate the intra-technique differences as presented in Table 3. The comparison of postoperative and uninjured side volumes measured using water displacement method was found have a statistically significant difference (p value 0.002). While comparison of the same within the other two methods was found to have no statistical significance. Comparison of preoperative and postoperative volumes within each technique revealed statistically significant difference between the same in all three methods as shown in Table 4. This difference in the water displacement technique was highly significant (p value 0.009). This implies that the correction of the orbital volumes was satisfactorily represented by the CT software and impression material volume techniques.

Table no 2: Comparison of the Postoperative side and Uninjured side orbital volumes using repeated measure ANOVA test

Parameters		Mean (Standard Deviation)	95% Confidence Interval		Repeated measure ANOVA
			Lower Bound	Upper Bound	
Postoperative	CT software program	22.88 (1.23)	21.740	24.020	**0.02**
	Impression materialtechnique	22.71 (0.756)	22.015	23.413	
	Water displacement method	20.14 (0.90)	19.311	20.975	
Uninjured	CT software program	22.72 (1.24)	21.572	23.882	
	Impression material technique	22.43 (0.97)	21.526	23.331	
	Water displacement method	22.71 (1.70)	21.138	24.291	

Table no 3: Pairwise comparisons from repeated measures ANOVA test

(I) factor	(J) factor	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Postoperative CT software program	PostoperativeImpression material technique	0.166	0.358	0.660	-0.710	1.042
	Postoperative Water displacement method	2.737*	0.494	**0.001**	1.529	3.945
	Uninjured CT software program	0.153	0.063	0.051	-0.001	0.307
	Uninjured Impression material technique	0.451	0.245	0.114	-0.147	1.050
	Uninjured Water displacement method	0.166	0.942	0.866	-2.139	2.471
Postoperative Impression material technique	Postoperative Water displacement method	2.571*	0.369	**0.000**	1.669	3.474
	Uninjured CT software program	-0.013	0.350	0.972	-0.869	0.843
	Uninjured Impression material technique	0.286	0.286	0.356	-0.413	0.985

	Uninjured Water displacement method	0.000	0.845	1.000	-2.068	2.068
Postoperative Water displacement method	Uninjured CT software program	-2.584*	0.504	**0.002**	-3.817	-1.352
	Uninjured Impression material technique	-2.286*	0.421	**0.002**	-3.315	-1.257
	Uninjured Water displacement method	-2.571*	0.869	**0.025**	-4.698	-0.445
Uninjured CT software program	Uninjured Impression material technique	0.299	0.248	0.274	-0.308	0.905
	Uninjured Water displacement method	0.013	0.946	0.990	-2.301	2.327
Uninjured Impression material technique	Uninjured Water displacement method	-0.286	0.944	0.772	-2.596	2.024

Table no 4: Paired sample t test for comparison of Preoperative and Postoperative orbital volumes

Parameters		**Mean (Std Deviation)**	**p Value**
CT software program	Preoperative	28.61 (5.69)	**0.025**
	Postoperative	22.88(1.23)	
Impression material technique	Preoperative	28.00 (5.42)	**0.036**
	Postoperative	22.71 (0.76)	
Water displacement method	Preoperative	26.71 (4.75)	**0.009**
	Postoperative	20.14 (0.90)	

DISCUSSION

The evolving techniques of orbital volume estimation are abounding with difficulty and disadvantages. In the present study, three orbital volume estimation techniques were used, two requiring the use of silicone putty impression material and one requiring use of CT software. The values obtained were compared. Furthermore, the use of STL models for recording pre and postoperative impression using silicone impression material has not been reported in literature so far, making this the first study to do so.

Orbital volume data was first published in the year 1873 in France by Gayat. He determined orbital volumes in skulls by filling the orbital cavities with lead pellets and then poured them into a graduated cylinder[5]. Consequently, other authors used this graduated cylinder method with different orbital fillers like dry sand, cellophane, hard seeds[3,5-7]. The use of casts to measure orbital volumes was substantiated by Sarnat in 1970 by filling rabbit orbits with an elastic rubber polymer and calculated the weight and specific gravity of the material and measured the volume by water displacement method. This method was based on Archimedean principles and was regarded as gold standard. Its major limitation was that it could not be used in vivo[5,8]. Similar imprint methods were employed by Kennedy[9]. Casts were used as the standard method by Cepela et al[10], McGurk et al [11], Deveci et al [12], and Koppel et al [13].

The development of medical imaging techniques facilitated the estimation of orbital volumes in living patients. The first of which was performed in 1960s on a living patient with the manual evaluation of roentgenographic images [5].

Abujamra in 1976, published “radiovolumetry of the orbit” based on the correlation of the manual measurements of orbital rim diameter from plain X-ray, with that obtained with lead pellet method. Today the use of this technique is not advised as only measurement of the entrance diameter of the bony orbit is not sufficient [5].

In 1985 Cooper formulated a method for orbital volume assessment in living patients using CT scans. He compared the measurements obtained with CT scan technique with the volume of dry sand in skulls and found a definite discrepancy between the two methods [14]. Following this, Forbes et al. estimated the volumes of different components of the orbit using CT scan assessment by pixel summation method [15]. Since then, many authors have tried to formulate methods to determine orbital volumes using CT scan acquisitions. They have compared their techniques to experimental methods like direct measurements with water displacement method to validate them and find the most accurate and reproducible method to determine orbital volume [11-13].

In the present study, CT software group allowed for more accurate estimation of orbital volume in decimal points when compared to the other two groups, which is similar to findings noted by other authors. The water displacement method was found to be the least accurate of all. This is in contrast to studies reported in literature. In 2000, a Turkish group compared the volumes of 20 orbits measured using 3D CT software program with direct measurement (paste casts of orbits submerged in water to measure displaced volume) and found no statistically significant differences between the methods[12]. The study by Acer et al, also found no difference in their study that compared CT stereological technique to measurements obtained with water filling method [16].

Irrespective of method employed, orbital volume estimation is fraught with difficulty due to the hyperbolic parabola shaped orbital entrance. Osaki et al suggests that, glass beads and casts provided more reproducible values but could only be used in cadaveric studies[5]. In contrast, CT technique is prone to inconsistencies in methodology and measurements are probably subject to bias and inter investigator differences, but can be applied to large sample studies by standardizing the technique.

Use of glass beads and dry sand require coating of the model orbit with separating mediums like plasticine, which can be avoided in our technique. The technique used by us is a novel technique that can be used in living patients by using STL models of CT scans. The impression material used is easily available, cost effective and easy to handle. Inexperienced clinicians may also be able to use this technique with ease, in comparison to the technique sensitive, challenging computerized software method that requires advanced training of personnel to perform volume estimation. Computerized software orbital volume estimation is an expensive arduous process that needs thorough knowledge and has a lot of inter observer differences. Institutions with 3D printing facilities will benefit from this technique.

CONCLUSION

The techniques of orbital volume estimation using impression material are simple, easily reproducible, do not require technical expertise and allow for volume estimation which can be closely matched with that of the software manual segmentation technique. In the clinical scenario, one need not rely on sophisticated software programs for orbital volume measurement but can proceed with these simpler techniques which can provide valuable and comparable alternative to CT software method. Also, the impression of the defect can aid in implant selection based of the extent, size and shape of the defect and may even give an incite as to the requirement of grafting. A larger study sample is a prerequisite for estimation of efficacy of this technique. However, it is a reliable technique and may be a useful addition for planning of surgical reconstruction of orbital defects which can be easily employed by inexperienced operators.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Compliance with Ethical Standards

Conflict of interest: The authors declare that they have no conflict of interest.

REFERENCES

[1]. Banica B, Ene P, Vranceanu D, Ene R. Titanium preformed implants in orbital floor reconstruction - case presentation, review of literature. Maedica. 2013 Mar;8(1):34–9.

[2]. Sukegawa S, Kanno T, Shibata A, Matsumoto K, Sukegawa-Takahashi Y, Sakaida K, et al. Treatment of Orbital Fractures with Orbital-Wall Defects using Anatomically Preformed Orbital Wall Reconstruction Plate System. J Hard Tissue Biol. 2017;26(2):231–6.

[3]. Sentucq C, Schlund M, Bouet B, garms martin, Jacques T, Ferri J, et al. Overview of tools for the measurement of the orbital volume and their applications to orbital surgery. J PlastReconstrAesthet Surg. 2020 Sep 20;74:1–11.

[4]. Jansen J, Schreurs R, Dubois L, Maal TJJ, Gooris PJJ, Becking AG. Orbital volume analysis: validation of a semi-automatic software segmentation method. Int J Comput Assist Radiol Surg. 2016 Jan;11(1):11–8.

[5]. Osaki TH, de Castro DK, Yabumoto C, Mingkwansook V, Ting E, Nallasamy N, et al. Comparison of methodologies in volumetric orbitometry. OphthalPlastReconstr Surg. 2013 Dec;29(6):431–6.

[6]. P'an TH. Measurement of the Chinese Orbit. J Anat. 1933 Jul;67(Pt 4):596-8.

[7]. Alexander JC, Anderson JE, Hill JC. The determination of orbital volume. Trans Can Opthalmolog Soc. 1961;24:105-11.
8. Sarnat BG. The imprint method to determine orbital volume in the rabbit. Ophthalmologica. 1970;160(3):142-51.

[8]. Kennedy RE. Growth retardation and volume determinations of the anophthalmic orbit. Trans Am Ophthalmol Soc. 1972;70:278–97.

[9]. Cepela MA, Nunery WR, Martin RT. Stimulation of orbital growth by the use of expandable implants in the anophthalmic cat orbit. OphthalPlastReconstr Surg. 1992;8(3):157–67; discussion 168-169.

[10]. McGurk M, Whitehouse RW, Taylor PM, Swinson B. Orbital volume measured by a low-dose CT scanning technique. DentoMaxillo Facial Radiol. 1992 May;21(2):70–2.

[11]. Deveci M, Oztürk S, Sengezer M, Pabuşcu Y. Measurement of orbital volume by a 3-dimensional software program: an experimental study. J Oral Maxillofac Surg Off J Am Assoc Oral Maxillofac Surg. 2000 Jun;58(6):645–8.

[12]. Koppel D, Foy R, Mccaul J, Logan J, Hadley D, Ayoub A. The reliability of "Analyze" software in measuring orbital volume utilizing CT-derived data. J Cranio-Maxillo-fac Surg Off PublEur Assoc Cranio-Maxillo-fac Surg. 2003 May 1;31:88–91.

[13]. Cooper WC. A method for volume determination of the orbit and its contents by high resolution axial tomography and quantitative digital image analysis. Trans Am Ophthalmol Soc. 1985;83:546–609.

[14]. Forbes G, Gehring DG, Gorman CA, Brennan MD, Jackson IT. Volume measurements of normal orbital structures by computed tomographic analysis. AJR Am J Roentgenol. 1985 Jul;145(1):149–54.

[15]. Acer N, Sahin B, Ergür H, Basaloglu H, Ceri NG. Stereological estimation of the orbital volume: a criterion standard study. J Craniofac Surg. 2009 May;20(3):921–5.