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Article

# Evaluation of Intraorbital Soft Tissue Modifications after Traumatic Injuries Management

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**Abstract:** Orbital fractures are a common finding in facial trauma and serious complications may arise when orbital reconstruction is not done properly. The virtual planning can be used to manufacture patient-specific titanium orbital implants (PSI) through the process of selective laser melting. This method is currently considered the most accurate technique for orbital reconstruction. Even with the most accurate techniques of bone reconstruction, there are still situations where enophthalmos is present after reconstruction which may be produced by intraorbital soft tissue atrophy. The aim of this paper was to evaluate the orbital soft tissue after postraumatic reconstruction of the orbital walls fractures. 10 patients diagnosed with unilateral orbital fractures were included in this study. A CT scan of the head region with thin slices (0.6mm) and soft and bone tissue windows was done. After data processing, the STL files were exported and the intraorbital fat tissue volume and the muscular tissue volume were measured. The volumes of affected orbit tissues were compared with the volumes of the healthy orbit tissues for each patient. Our findings conclude that a higher or a lower grade of fat and muscular tissue loss is present in all cases of reconstructed orbital fractures.

**Keywords:** soft; tissue; orbit; trauma; reconstruction; PSI; segmentation; enophthalmos

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## 1. Introduction

Orbital fractures are a common finding in facial trauma. An increased percent of patients with orbital fractures undergo surgical treatment but there are still cases which are treated conservatively due to the different reasons [1-4]. Serious complications may arise when orbital reconstruction is not done properly. These include enophthalmos, hypoglobus, diplopia, restricted motility, and muscle entrapment [4-8].

The anatomy of the orbital cavity is complex and the reconstructive procedures in the orbital region are particularly difficult. The s-shaped orbital floor and the transition zone between the medial and the inferior wall can be challenging for reconstruction. The aim of reconstruction is to restore perfectly the orbit in all three dimensions in order to avoid esthetic and functional complications [9,10].

The first step to orbital surgery is an adequate exposure of the internal orbital walls. Selecting the appropriate surgical approach is mandatory [11]. The reconstruction of the bony walls can be done with resorbable and non-resorbable materials. The non-resorbable materials are preferred due to their predictability and stable results. Titanium implants can be found as standard preformed orbital plates or individualized orbital implants. The standard plates are available in different sizes and can provide good results as long as they are placed in the correct position. The individualized implants use computer-aided design (CAD) which shares a virtual plan based on the patient's 3D scan. All types of CAD based individualized orbital implants require preoperative computerized planning. The scan will be transferred to the planning software where the unaffected orbit can be

mirrored to fit the affected side. From this point, physical biomodels of the virtually reconstructed orbit can provide 3D models. On these models, titanium meshes can be designed, bent, and sterilized preoperatively, together with the biomodel for intraoperative application [12-15].

The virtual planning can be used to manufacture patient-specific titanium orbital implants (PSI) through the process of selective laser melting. This method is currently considered the most accurate technique for orbital reconstruction [16,17]. The PSI is not malleable and avoids human error during the pre bending stage. The implant is designed with rounded edges so that the implant does not traumatise the soft tissue. Also navigational target points can be designed on the surface of the implant. All these lead to a very precise implant that can be very accurately placed [18].

Even with the most accurate techniques of bone reconstruction, there are still situations where enophthalmos is present after reconstruction which may be produced by intraorbital soft tissue atrophy. Orbital soft tissues, including extraocular muscles and intraorbital fat, are the most important components of orbital contents, accounting for approximately 50% of orbital cavity volume [19,20]. The change in volume of the soft tissue, following orbital trauma, may lead to diplopia, restricted ocular movement and even impairment of visual function [21,22]. Precise assessment of intraorbital soft tissue is essential for diagnosis of intraorbital disorders, effect evaluation of treatment and planning for surgical intervention [23-28]. Computerized tomography (CT) and magnetic resonance imaging (MRI) are the main imaging methods to examine intraorbital soft tissues. Several studies have focused on segmenting the interested tissues of orbit using semiautomatic or even automatic approaches based on computer image processing techniques [29-32]. However, due to the complicated structure and the small volume of the orbit, as well as the unclear boundary of soft tissues in CT images, effective and precise segmentation of intraorbital fat and extraocular muscles remains a tough task [33].

The aim of this paper was to evaluate the orbital soft tissue after posttraumatic reconstruction of the orbital walls fractures.

## 2. Materials and Methods

After applying the exclusion criteria, 10 patients diagnosed with unilateral orbital fractures were included in this study. All 10 were treated in the same hospital, by the same surgeon, with the same surgical approach. In 3 cases patient specific implants (PSI) were used. For the rest of 7 we used prebended titanium meshes on stereolithographic models which were obtained through mirroring technique. All patients were evaluated after a minimum of 6 months after surgery. A very low degree of enophthalmos was present in all cases.

Several parameters were taken into consideration for the analysis, among which: the sex of the patients, the number of affected orbital walls, the bilateral orbital bony volume, the volume of the bilateral orbital fat tissue, as well as the volume of the bilateral orbital muscles.

A CT scan of the head region with thin slices (0.6mm) and soft and bone tissue windows was done. The DICOM (Digital Imaging and Communications in Medicine) files, resulting from the CT scan, were imported into the Slicer program, in order to obtain the 3D reconstructions. Slicer, version 4.11, is a semi-automatic software, used to visualize and analyze the data obtained with the help of imaging. In order to obtain 3D segmentations, the processing of DICOM files was carried out using the hard and soft tissue window of the CTs. The densities used (gray level) were as follows: from -200 to 100 Hounsfield units (HU) for the total orbital volume (figure 1); -200 to 15 HU for the fat volume of the orbit (figure 2); -30 to 200 HU for muscle tissue volume (figure 3).

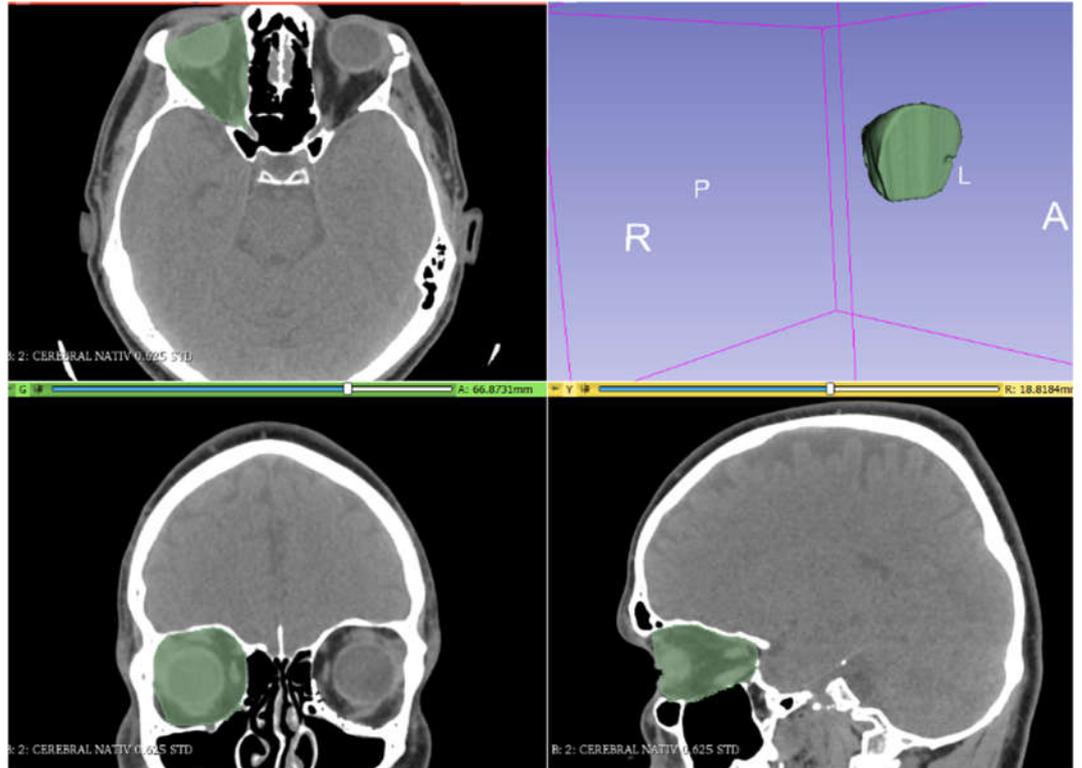


Figure 1. Segmentation of the volume of bony orbit.

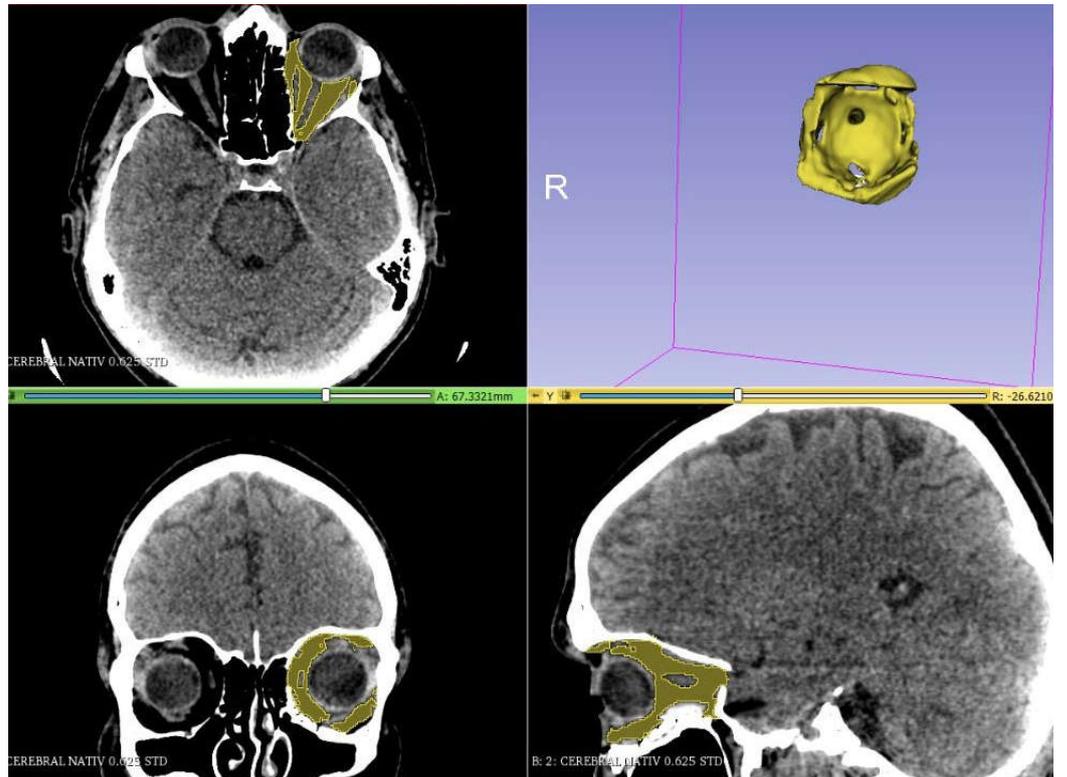
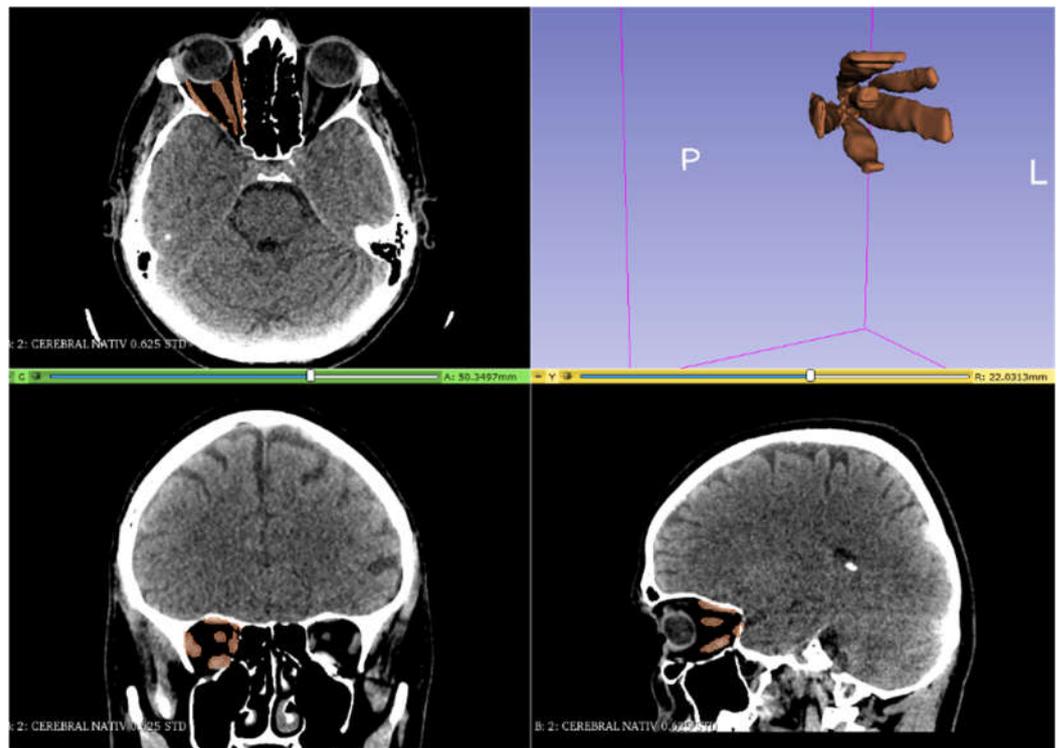
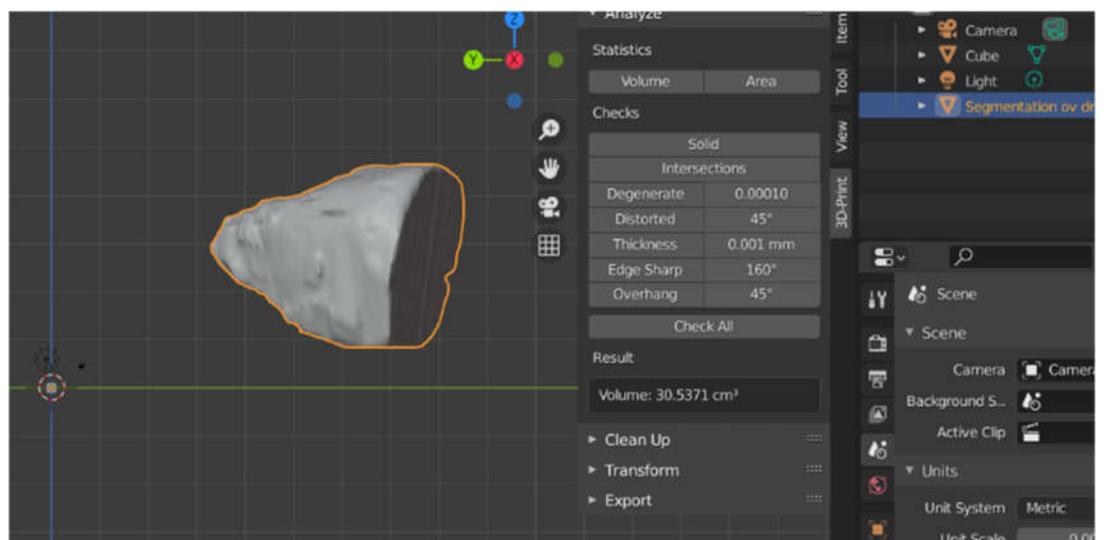


Figure 2. Segmentation of orbital fat tissue.



**Figure 3.** Segmentation of orbital muscles.

The 3D reconstructions were exported as STL (Standard Triangle Language/Standard Tessellation Language) files, which allowed the use of the Blender 3D Software for volume calculation. The values obtained were measured in cubic centimeters (cm<sup>3</sup>), so after importing the STL file, we have adjusted the unit scale to the value of 0.001 and the length in millimeters, so that later, by simply selecting the 3D-volume section, the volume of segmentation in cm<sup>3</sup> was displayed (figure 4,5,6).



**Figure 4.** The volume of bony orbit in cm<sup>3</sup>.

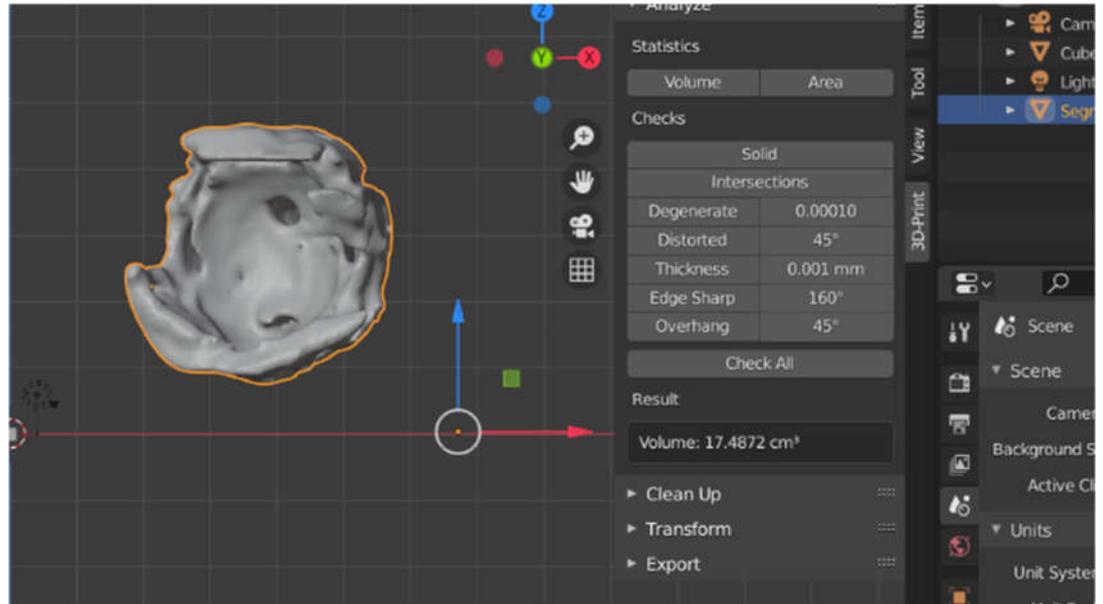


Figure 5. The volume of fat tissue in cm<sup>3</sup>.

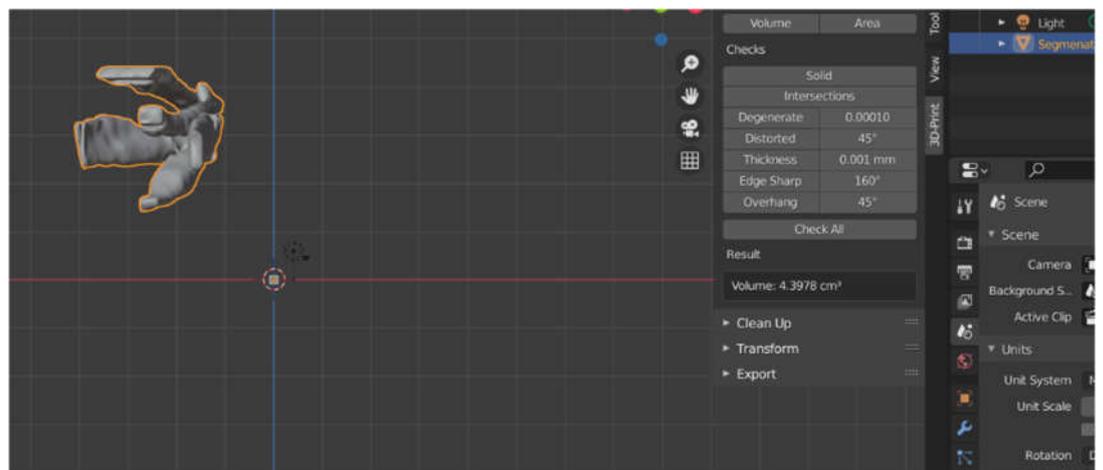


Figure 6. The volume of orbital muscles in cm<sup>3</sup>.

### 3. Results

A total of 20 orbits were analyzed. The bony volume of the affected orbit (AOV), respectively of the healthy orbit (HOV), the fat volume of the affected orbit (AFV), respectively the fat volume of the healthy orbit (HFV), the muscles volume of the affected orbit (AMV), respectively the muscles volume of the healthy orbit (HMV), the number of fractured walls and the sex of the patients are systematically presented, as follows in Table 1:

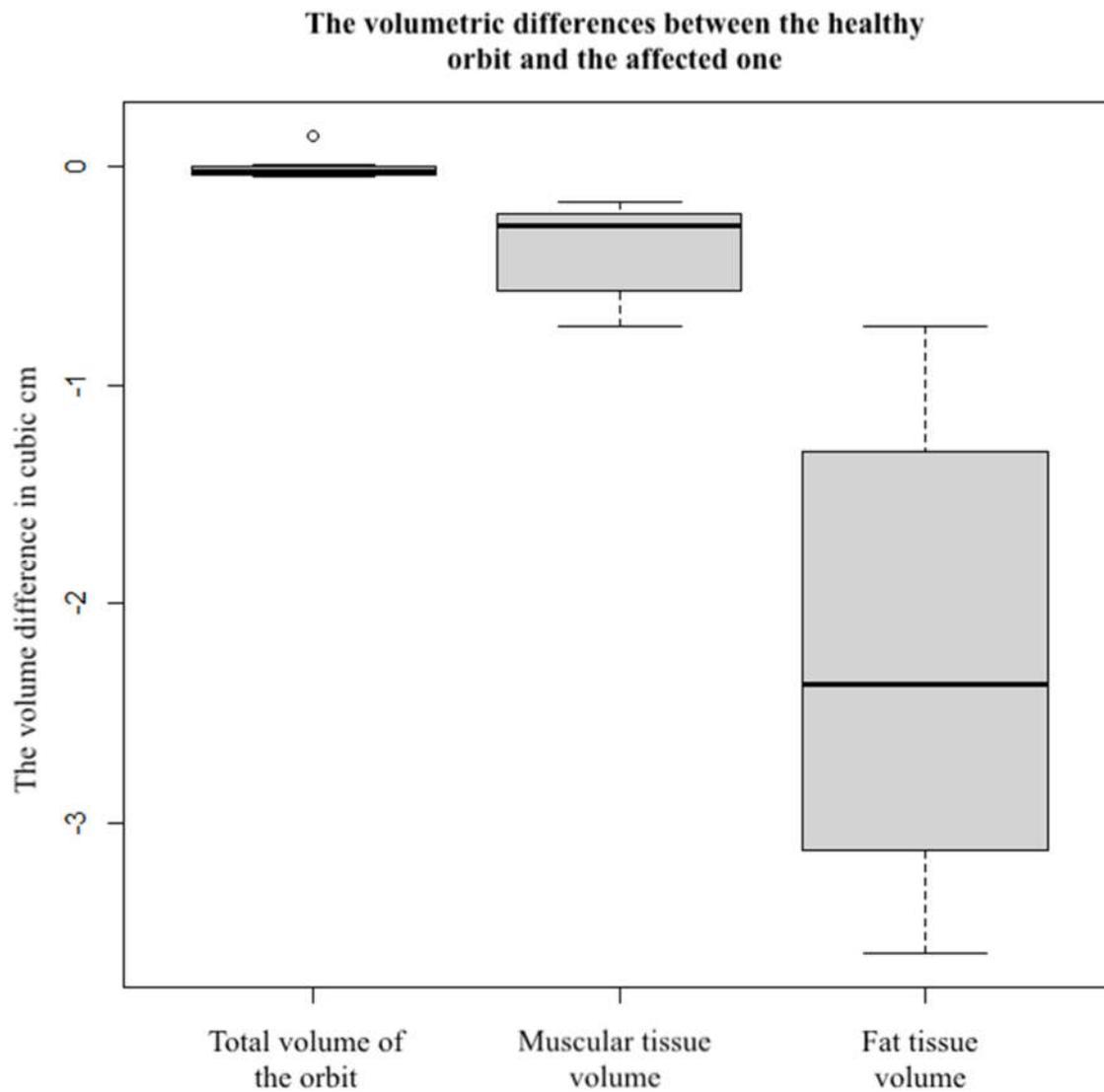
**Table 1.** Systematisation of the main results.

Nr.	Affected orbit	AOV	HOV	AFV	HFV	AMV	HMV	Number of affected walls	Gender
Case 1	R	27,15	27,01	13,91	14,64	3,48	4,21	1	F
Case 2	L	24,45	24,49	11,96	13,27	3,01	3,59	2	F
Case 3	L	25,15	25,14	7,93	10,16	3,79	3,95	1	F
Case 4	R	25,62	25,66	10,85	13,04	3,86	4,12	1	F
Case 5	L	30,52	30,54	14,36	17,49	4,20	4,39	2	M
Case 6	R	27,60	27,63	12,02	15,62	3,42	3,99	3	M
Case 7	R	28,03	28,02	14,42	15,19	4,40	4,67	3	M
Case 8	L	31,19	31,24	16,10	18,67	4,33	4,57	1	M
Case 9	R	30,47	30,46	13,41	16,68	4,43	4,70	2	M
Case 10	L	28,29	28,27	13,00	15,50	4,46	4,68	2	M

Regarding the number of fractured walls, 4 patients had one fractured wall, 4 patients had 2 fractured walls, and 2 patients had 3 fractured walls. We did not find any statistical correlation between the number of fractured walls and the volume of the soft tissue atrophy.

The differences (delta) between the affected orbit and the healthy orbit (control) are shown in tables 2, 3 and 4. Regarding the total orbital volume, the differences were minimal, with a maximum of 0.05 cm<sup>3</sup> and a minimum of -0.14 cm<sup>3</sup>, without any correlation between a larger volume and the affected orbit. Referring to fat and muscular volume, it could be found that the volume of the affected orbit in the case of each variable was lower (delta with significant volumetric differences) compared to the healthy orbit (control) (figure 7).

The volume of fat tissue was lower in all affected orbits with a minimum of 0.73 cm<sup>3</sup>, maximum of 3.60 cm<sup>3</sup> and a mean of 2.228 cm<sup>3</sup> (p<0.001). Also the musculature was affected in all fractured orbits. The minimum was 0.16 cm<sup>3</sup>, maximum 0.73 cm<sup>3</sup> and the mean was 0.348 cm<sup>3</sup> (p<0.001).



**Figure 7.** Volumetric differences between the healthy orbit and the affected one.

**Table 2.** Volume measurement of the bony orbit.

Nr.	HOV	AOV	Delta
Case 1	27.01	27.15	-0.14
Case 2	24.49	24.45	0.04
Case 3	25.14	25.15	-0.01
Case 4	25.66	25.62	0.04
Case 5	30.54	30.52	0.02
Case 6	27.63	27.60	0.03
Case 7	28.02	28.03	-0.01
Case 8	31.24	31.19	0.05
Case 9	30.46	30.47	-0.01
Case 10	28.29	28.27	0.02

**Table 3.** Volume measurement of the fat tissue.

Nr.	HFV	AFV	Delta
Case 1	14.64	13.91	0.73
Case 2	13.27	11.96	1.31
Case 3	10.16	7.93	2.23
Case 4	13.04	10.85	2.19
Case 5	17.49	14.36	3.12
Case 6	15.62	12.02	3.60
Case 7	15.19	14.42	0.77
Case 8	18.67	16.10	2.56
Case 9	16.68	13.41	3.27
Case 10	15.50	13.00	2.50

**Table 4.** Volume measurement of the muscular tissue.

Nr.	HMV	AMV	Delta
Case 1	4.21	3.48	0.73
Case 2	3.59	3.01	0.58
Case 3	3.95	3.79	0.16
Case 4	4.12	3.86	0.26
Case 5	4.39	4.20	0.19
Case 6	3.99	3.42	0.57
Case 7	4.67	4.40	0.27
Case 8	4.57	4.33	0.25
Case 9	4.70	4.43	0.27
Case 10	4.68	4.46	0.2

Regarding the normal volume of the orbit we found that females orbits were smaller, with a mean of 3.81 cm<sup>3</sup>, the fat volume was lower with a mean of 3.75 cm<sup>3</sup> and the muscle volume was also lower with a mean of 0.68 cm<sup>3</sup> (p<0.01) (table 5).

**Table 5.** - Average and standard deviation.

Gender	HOV	AOV	HFV	AFV	HMV	HMV
F	25.57 ± 1.07	25.59 ± 1.14	12.78 ± 1.88	11.16 ± 2.50	3.97 ± 0.27	3.535 ± 0.39
M	29.38 ± 1.55	29.35 ± 1.55	16.53 ± 1.36	13.89 ± 1.41	4.50 ± 0.27	4.21 ± 0.4

#### 4. Discussion

The benefit of computer-assisted planning and computer-assisted surgery in orbital reconstruction has been well documented lately, permitting a safe procedure with predictable results. The orbit has a complex 3D shape. Even if we talk about printing stereolithographic models and pre-bending titanium meshes or printing directly a titanium implant, the results are much better than working without a CAD system [16,34,35].

Manually shaped titanium meshes achieve a very good approximation of the ideal reconstruction based on a 3D printed model but designing and manufacturing the implants based on virtual models produce the most accurate implants [26-28]. Zimmerer et al. concluded that individualized orbital implants, particularly CAD-based ones, allow for a more precise post traumatic orbital reconstruction than standard preformed implants [15]. We did not find a significant difference between these two, but our echantion was smaller.

Poor primary reconstruction may lead to increased orbital volume and muscle restrictions. Persistent enophthalmos will lead to unacceptable aesthetic results. Diplopia is

another functional poor outcome which is hardly accepted by the patient even if wearing correction glasses might slightly improve the situation. Although there is a debate whether these complications are mainly because of enlargement of the bony orbit or soft tissue atrophy, a good bony reconstruction and repositioning or augmentation of orbital soft tissues can improve clinical results [39,40].

There are also situations when the bony orbit is perfectly reconstructed, as we have shown, but the patient still presents enophthalmos due to the soft tissue atrophy. In these cases, estimating the need of overcorrection of the globe position depends mainly on the clinical evaluation. Our study found mean values for fat tissue and muscular tissue atrophy which can be useful for guiding the soft tissue correction.

For this correction several autogenous and alloplastic materials can be used. The autogenous grafts can be time consuming and involve donor site morbidity. The amount of volume reduction needed is difficult to estimate because the behaviour of the soft tissue is different among patients [41].

Titanium spacers are designed in different sizes and represent a very good solution for compensation of orbital soft tissue atrophy. In their study Spalthoff et al. concluded that augmentation of the intraorbital volume using titanium spacers remains a reasonable method to correct orbital deformities in delayed primary and secondary orbital reconstruction [42].

## 5. Conclusions

The anatomy of the orbital cavity is complex and needs very accurate reconstruction. Virtual planning and customised solutions, such as PSI or prebent titanium meshes conformed on stereolithographic models offer predictable solutions and accurate results. Nevertheless, there are cases where very reduced enophthalmos is still present after surgical treatment. A higher or a lower grade of fat and muscular tissue loss is present in all cases of reconstructed orbital fractures. Our calculation of the mean value of lost volume can stand as a guide for primary or secondary soft tissue augmentation, but larger studies are necessary.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

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