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Can a Specific Computed Tomography-Based Assessment Predict the Ophthalmological Outcome in Pure Orbital Floor Blowout Fractures?

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Abstract: The aim of this study was to determine the predictive value of a specific computed tomography (CT)-based assessment for the final functional ophthalmological outcome in pure orbital floor blowout fractures. Data of 34 consecutive patients with pure blowout fractures who had undergone a period of at least 6 months of medical and ophthalmological follow-up were analyzed. The following 3 CT scan-based parameters were included: area ratio of the fractured orbital floor (RF), maximum height of periorbital tissue herniation (MH), and a 4-grade muscular subscore (MSS) describing the inferior rectus muscle displacement relative to the orbital floor level. The orthoptic complications (diplopia, enophthalmos, and ocular motility restriction) were evaluated by an experienced strabologist. The CT parameters' predictive value was analyzed using receiver operating characteristic curves and area under the curve (AUC), logistic regression, and Spearman correlation.

The RF had a significant predictive value for enophthalmos appearance ($AUC = 0.75$, $P = 0.02$), and MH for diplopia ($AUC = 0.80$, $P = 0.03$). Among patients with complications, the relevance of MSS and MH as well as the severity of vertical deviation were also clinically strongly associated ($rho = -0.52$ and -0.56).

Our study revealed the significantly predictive value of RF for occurrence of enophthalmos and of MH for diplopia persistence. Although statistically unable to predict the occurrence of ocular motility restriction, MH and MSS were clinically strongly correlated with the severity of ocular deviation limitations.

Key Words: CT scan, ocular motility, ophthalmological outcome, pure orbital fracture

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Although orbital floor blowout fractures (BOFs) are very common and their incidence is steadily increasing, paradoxically their management still remains a source of debate.[1] Even when apparently well managed, these fractures may be associated with residual long-term complications such as oculomotor disorders and/or enophthalmos, which can potentially result in annoying diplopia that interferes with common daily activities and thus with the quality of life.[1]

There is no accepted standard management for BOFs. Rather, individual clinics worldwide have developed their own preferred combination of radiologic and clinical criteria that include ocular motility evaluation, the presence of enophthalmos and/or hypoglobus, the size and type of fracture, and the presence of associated facial fracture.[2] Thus, in daily practice, BOFs are mainly assessed on the basis of a surgeon's subjective and "empirical-based" clinical judgment. Typically, the final treatment is decided according to specific in-house decision-making algorithms rather than by using standardized and consensual international guidelines simply because they are not available.

Over the past few years, the general trend has moved toward quantifying the lesions, so as to determine the extent of the fractures. Multiple radiologic diagnostic criteria developed using computed tomography (CT) have tried to establish the relationships between the images observed and the associated clinical signs and symptoms.[3–10] Some of these criteria have already demonstrated their utility and reliability for a therapeutic decision-making strategy for pure BOFs.[6,10]

Studies have been mainly focused on the prevalence of diplopia in patients with BOFs, the possible association between orbital volume and severity of enophthalmos development and the possible beneficial effect of surgical treatment on the functional status of ocular motility.

Thus far, few studies have been published reporting on the possible radiologic predictors for sequellar oculomotor disorders and/or persistent enophthalmos in patients receiving either conservative or surgical treatment.[4,11–16]

The purpose of the current study was thus to determine the predictive value of previously validated CT-based radiologic parameters for the final functional ophthalmological outcome in patients with pure BOFs.

METHODS

The protocol of this prospective cohort study was reviewed and approved by our local ethics committee based on the guidelines of the Declaration of Helsinki of 1975, as revised in 2000.

Study Design

The study population was composed of all patients presenting to the Maxillofacial Surgery Division of the University Hospitals of Geneva, Switzerland, between 2012 and 2015 for the evaluation and

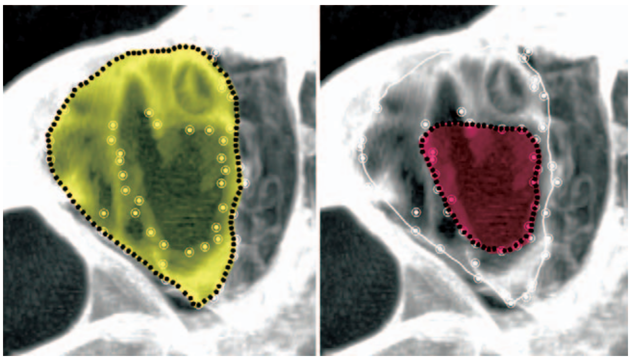

FIGURE 1. Axial CT scan slices showing the area ratio of the fractured orbital floor (RF, fracture area [red]/total orbital floor area [yellow]). CT, computed tomography.

management of BOFs. All patients with isolated and displaced pure BOFs at the initial presentation who had undergone a period of at least 6 months of medical and ophthalmological follow-up were included and clinical and CT scan data analyzed.

Exclusion criteria were as follows: <6 months of follow-up, previous history of orbital and/or ophthalmologic surgery, simple linear fracture of the orbital floor with no displacement on CT scan, impure orbital fractures, combined orbital floor and medial wall fractures, bilateral fractures, and monocular vision or nonstereoscopic vision.

Treatment

Surgical management was proposed based upon our following in-house criteria: orbital floor defect size of >50% of the entire orbital floor as measured according to the computational method previously described by Schouman et al[9–10] and evidence of periorbital soft tissue and/or inferior rectus muscle herniation within the maxillary sinus on CT scan; immediate ocular motility restriction in at least one field of gaze or annoying diplopia at the 10-day follow-up examination; and enophthalmos immediately obvious to the naked eye or $\geq$2 mm difference between the globe projection of the 2 eyes as measured by Hertel exophthalmometry at the 10-day follow-up examination.

Image Acquisition

Facial bone CT scans were obtained using GE Healthcare's CT750 HD scanning system with the following parameters: 120 mkV, 150 to 175 mA, 512 $\times$ 512px, in accordance with the bone acquisition protocol recommended by the manufacturer's user guide (http://www3.gehealthcare.com).

Computer Image Analysis

The Digital Imaging and Communications in Medicine data were processed using OsiriX imaging software (version 3.0.2, 64-bit; Pixmeo, Geneva, Switzerland, www.osirix-viewer.com) running on a MacOSX 10.8.5 (Apple Inc, Cupertino, CA).

For each patient, the following 3 parameters were calculated according to the computational method previously described and validated by Schouman et al.[9,10]

(1) Area ratio of the fractured orbital floor (RF = fracture area/ total orbital floor area) (Fig. 1).

(2) Maximum height of periorbital tissue herniation (MH = max- maximum distance between a virtual line connecting the medial and lateral boundaries of the orbital floor and the most inferior point of the periorbital tissue) (Fig. 2).

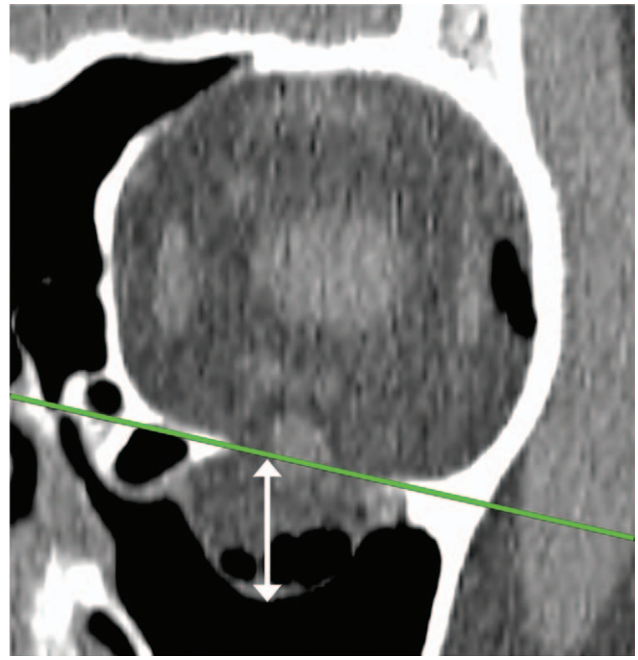

FIGURE 2. Coronal CT scan slices showing the maximum height of periorbital tissue herniation (MH, maximum distance between a virtual line connecting the medial and lateral boundaries of the orbital floor and the most inferior point of the periorbital tissue). CT, computed tomography.

(3) Inferior rectus muscle displacement relative to the level of the orbital floor (evaluated using a muscular subscore [MSS] subdivided into four grades) (Fig. 3).

Clinical Examination

An extended ophthalmological assessment was carried out by an experienced strabologist (RDH) by using the following examinations: distance and near visual acuities, Hertel exophthalmometry, corneal light reflex (Hirschberg test), ductions and versions in the 6 cardinal fields of gaze, eye deviation with prisms and alternate cover test in all 9-gaze directions with Maddox rod, degrees of incyclo/excyclotorsion with right and then left eye fixation, horizontal and vertical deviation with Hess-Weiss coordimetry, and degree of horizontal/vertical and incyclo/excyclotorsion deviation with Harms wall deviometry.

Enophthalmos was defined as a difference of $\geq$2 mm between the 2 eyes as measured by Hertel exophthalmometry.

The other variables reviewed included age and sex, etiology of trauma, time between trauma and examination, and residual visual axis deviations.

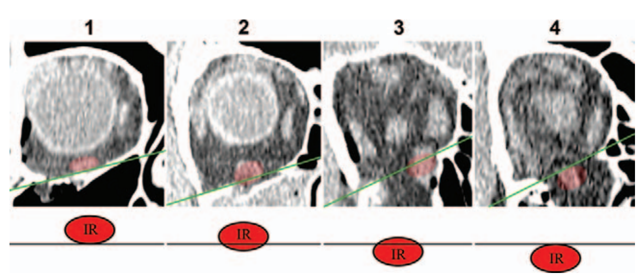

FIGURE 3. Coronal CT scan slices and schematics of right fractured orbits representing the muscle subscore (MSS). CT, computed tomography; IR, inferior rectus muscle.

TABLE 1. Baseline Data and Initial CT Assessment of the 3 Parameters

Patient No.	Sex	Age, y	Etiology	Treatment	Surgery Delays, d	RF	MH, mm	MSS
1	F	82	Fall	S	14	0.41	13.56	3
2	F	49	Sport accident	S	8	0.42	6.97	3
3	F	26	Assault	S	16	0.63	2.83	1
4	M	50	Traffic accident	S	5	0.37	4.20	1
5	M	25	Assault	S	4	0.49	5.55	2
6	F	71	Fall	S	5	0.36	14.78	4
7	F	41	Assault	S	10	0.48	3.78	1
8	M	24	Assault	S	4	0.33	11.79	2
9	M	44	Traffic accident	S	9	0.48	7.63	1
10	M	42	Fall	S	0	0.57	11.54	3
11	F	69	Fall	S	6	0.41	4.92	1
12	F	30	Traffic accident	S	12	0.25	2.85	1
13	F	49	Assault	S	12	0.31	6.89	3
14	M	41	Fall	S	9	0.29	2.72	1
15	F	13	Assault	S	0	0.27	8.14	1
16	M	31	Fall	S	2	0.25	5.72	2
17	M	48	Assault	S	12	0.45	12.58	2
18	F	67	Fall	S	12	0.37	8.26	3
19	M	30	Assault	S	13	0.39	5.12	1
20	M	24	Assault	S	1	0.46	6.21	1
21	M	27	Assault	C	None	0.21	1.56	1
22	M	19	Fall	C	None	0.09	0.00	1
23	M	45	Fall	C	None	0.30	3.99	2
24	M	24	Assault	C	None	0.12	7.43	1
25	F	59	Sport accident	C	None	0.32	6.75	2
26	M	78	Traffic accident	C	None	0.02	0.00	1
27	M	67	Fall	C	None	0.36	8.42	2
28	M	18	Work accident	C	None	0.04	2.11	1
29	F	86	Fall	C	None	0.21	5.49	1
30	M	23	Assault	C	None	0.30	11.24	1
31	M	24	Assault	C	None	0.13	7.77	1
32	F	70	Fall	C	None	0.31	3.95	1
33	F	78	Fall	C	None	0.33	12.92	1
34	F	43	Fall	C	None	0.50	10.27	3

C, conservative; CT, computed tomography; MH, maximum height of periorbital tissue herniation; MSS, muscular subscore; RF, area ratio of the fractured orbital floor; S, surgical.

Statistical Analysis

Data were analyzed using R statistical software (v. 3.2.2). We first dichotomized the ophthalmological measures (ie, horizontal deviation, vertical deviation, enophthalmos, or diplopia) as present or absent. The ability of the 3 CT scan analysis parameters to predict each of these dichotomized outcomes was assessed using receiver operating characteristic curves and area under the curve (AUC), as well as logistic regression to estimate crude odds ratio (OR).

In addition, among patients who had some complication (ie, vertical or horizontal ocular motility restrictions, or enophthalmos different from 0), we assessed the association between the ophthalmological measures that were different from 0 and the CT analysis parameters using Spearman correlation.

RESULTS

Sample Description

This study was conducted in 34 patients with an isolated orbital floor fracture. Nineteen patients (55.9 %) were men and 15 (44.1 %) women. Mean age at the time of trauma was 44.1 years (±SD 21.2 y; range 13–86 y). Etiologies of the fractures were as follows: 14 falls (41.2 %), 13 physical assaults (38.2 %), 4 road accidents (11.8 %), 2 sports accidents (5.9 %), and 1 accident at work (2.9 %). Twenty patients (58.8 %) had undergone a surgical procedure, and 14 patients (41.2 %) were conservatively managed. The mean time to operation was 7.7 days (±SD 4.9 d; range 0–16 d). The mean period of ophthalmological follow-up was 10.8 months (±SD 3.2 mo; range 7–16 mo). Characteristics of the sample are shown in Table 1.

Ophtalmological Complications

The MH was significantly associated with diplopia (OR = 1.28, AUC = 0.80, $P = 0.03$) (Table 2). The RF significantly predicted enophthalmos (OR = 2.40 for an increase in RF of 0.1, AUC = 0.75, $P = 0.02$) and showed a clinically strong, although not statistically significant, association with vertical ocular motility restriction (OR = 1.91, AUC = 0.69, $P = 0.09$). The MSS also showed a clinically important but not significant relation with diplopia (OR = 2.70, AUC = 0.71, $P = 0.08$). However, none of the 3 radiologic parameters measured was found to be a statistically significant predictor of specific horizontal ocular motility restriction.

TABLE 2. Area Under the Receiver Operating Characteristic Curve of Each Symptom

	Vertical Ocular Deviation (n = 9 of 34)			Horizontal Ocular Deviation (n = 12 of 34)			Enophthalmos (n = 12 of 34)			Diplopia (n = 6 of 34)		
	OR	AUC	*P*	OR	AUC	*P*	OR	AUC	*P*	OR	AUC	*P*
RF	1.91	0.693	0.09	0.91	0.438	0.56	2.40	0.748	0.02	1.76	0.693	0.15
MSS	1.82	0.622	0.23	1.23	0.525	0.81	1.23	0.525	0.81	2.70	0.708	0.08
MH	1.08	0.596	0.41	1.06	0.551	0.64	1.07	0.557	0.60	1.28	0.798	0.03

The odds ratio for RF corresponds multiplicative ratio of the odds for a 10% increase in RF.

AUC, area under the curve; MH, maximum height of periorbital tissue herniation; MSS, muscular subscore; OR, odds ratio; RF, area ratio of the fractured orbital floor.

All surgical patients had a complete repositioning of incarcerated periorbital tissue herniation, so that the MH on the postoperative CT scan was no longer measurable. Thus, in this particular subgroup the postoperative diplopia found in 5 patients (patients no. 2, 6, 9, 10, and 15) was not associated with postoperative persistent MH. In the conservative group, only 1 patient (patient no. 32) had a persistent diplopia, which was related to a concomitant enophthalmos. The MH has not been measured in conservative treated patients because they only had an initial immediate posttraumatic CT scan and were then followed exclusively by clinical examination. However, in none of these patients did diplopia interfere with daily activities or require corrective strabismus surgery.

Severity of Ophthalmological Anomalies

Among patients diagnosed with ophthalmological anomalies, graphical analyses showed an association between the relevance of the radiologic parameter and the severity of the anomaly (Table 3; Fig. 4). In particular, MSS and MH were moderately to strongly associated with vertical deviation (Spearman rho = −0.52 and −0.56, respectively) according to cutoff values recommended by Cohen.[17] However, these associations, although clinically large according to Cohen's thresholds, were not significant due to the small sample size in this pilot study.

Horizontal Versus Vertical Ocular Motility Restriction

Horizontal gaze limitation was found to be related to a preexisting condition such as exophoria, esophoria, and microstrabism in 8 patients (67%), to the fracture (limitation in extreme abduction gaze) in 3 patients (25%), and to a posttraumatic paralysis of the abducens nerve in 1 patient (8%) (Table 4).

TABLE 3. Spearman Correlation Between Each Symptom Level and the Predictors Among Symptomatic Patients

	Vertical Ocular Deviation (N = 9)		Horizontal Ocular Deviation (N = 12)		Enophtalmos (N = 12)	
	rho	*P*	rho	*P*	rho	*P*
RF	−0.31	0.41	0.23	0.48	−0.27	0.39
MSS	−0.52	0.15	0.24	0.45	−0.31	0.32
MH	−0.56	0.12	0.15	0.64	−0.16	0.62

MH, maximum height of periorbital tissue herniation; MSS, muscular subscore; RF, area ratio of the fractured orbital floor.

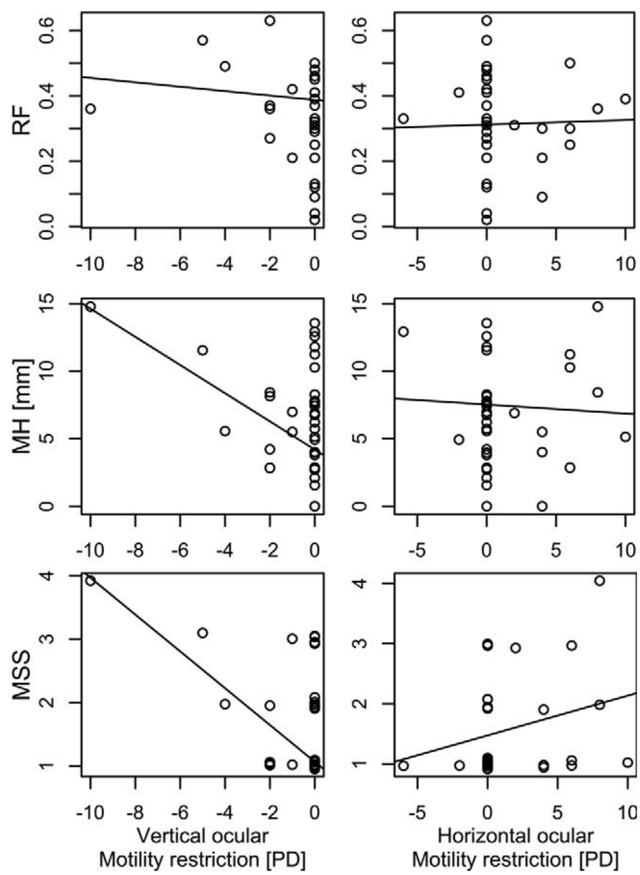

FIGURE 4. Graphical analyses showing the association between the relevance of the radiologic parameter and the severity of the orthoptic anomaly.

Vertical gaze limitation was found in 9 patients, among which 8 (89 %) had limitation of extreme upgaze in abduction and 1 (11 %) had limitation of extreme upgaze in adduction.

DISCUSSION

On the basis of the hypothesis that clinical and functional prognosis of isolated pure BOF could be associated with initial CT scan characteristics, our study aimed to demonstrate the possible value of 3 specific CT scan parameters (RF, MH, and MSS) in predicting the development of long-term ophthalmological sequelae. Of the 3 CT parameters studied, we found RF to be significantly predictive for the occurrence of long-term enophthalmos, and MH for the occurrence of diplopia. Although unable to predict the appearance of ocular motility restriction, our results did show a trend toward a strong correlation between the extent of MH and MSS and the severity of ocular motility restrictions.

There are currently few criteria for determining the radiologic predictability of prognosis in patients with an isolated orbital floor fracture.[13] The published prognostic factors associated with the persistence of long-term ophthalmological sequelae are primarily clinical and include the presence of severe preoperative diplopia and young age.[18–20]

Radiologically, the main factor reported to be associated with persistent diplopia is contracture of the inferior rectus muscle.[11] The presence of such a lesion is mainly based on detecting muscle edema, which is evaluated by establishing a ratio relative to the contralateral muscle. In 2011, Matsunaga et al[14] based their study on the area of the inferior rectus muscle on coronal images. Their

TABLE 4. Follow-Up Orthoptic Evaluation and Strabological Diagnosis

Patient No.	Follow-Up, mo	Diplopia*	Enophtalmos†	Horizontal Deviation, PD	Vertical Deviation, PD	Strabological Diagnosis
1	14	No	No	0	0	—
2	14	Yes	No	0	−1	Upward and abduction gaze limitation
3	16	No	Yes	0	−2	Upward and abduction gaze limitation
4	13	No	No	0	−2	Upward and abduction gaze limitation
5	14	No	No	0	−4	Upward and adduction gaze limitation
6	13	Yes	Yes	8	−10	Upward and abduction gaze limitation
7	13	No	No	0	0	Nihil
8	12	No	No	0	0	Nihil
9	12	Yes	Yes	0	0	Nihil
10	16	Yes	Yes	0	−5	Upward and abduction gaze limitation
11	7	No	Yes	−2	0	Exophoria‡
12	9	No	Yes	6	0	Exophoria‡
13	14	No	Yes	2	0	Esophoria‡
14	12	No	No	0	0	Nihil
15	12	Yes	No	0	−2	Upward and abduction gaze limitation
16	7	No	No	0	0	Nihil
17	7	No	Yes	0	0	Nihil
18	7	No	No	0	0	Nihil
19	7	No	Yes	10	0	Microstrabismus‡
20	8	No	Yes	0	0	Nihil
21	7	No	No	0	0	Nihil
22	13	No	No	4	0	Esophoria‡
23	14	No	No	4	0	Esophoria‡
24	9	No	No	0	0	Nihil
25	13	No	No	0	0	Nihil
26	8	No	No	0	0	Nihil
27	13	No	Yes	8	−2	Upward and abduction gaze limitation
28	7	No	No	0	0	Nihil
29	7	No	No	4	0	Upward and abduction gaze limitation
30	7	No	No	6	0	Esophoria‡
31	7	No	No	0	0	Nihil
32	7	No	Yes	0	0	Nihil
33	7	No	No	−6	0	Microstrabismus‡
34	14	No	No	6	0	Abducens nerve paralysis‡

PD, prism dioptres.
*Evaluated by assessment of ductions and versions in the six cardinal fields of gaze by asking the patient to follow the examiner's finger without moving the head.
†Evaluated by Hertel exophthalmometry.
‡Coincidental finding not related to the fracture.

results in 18 surgically treated patients found an association between an increase in the inferior rectus muscle swelling rate above a threshold of 1.6 and the persistence of binocular diplopia and ocular motility abnormalities at 1 year. In 2013, Kang et al[21] presented a similar study in 35 patients using muscle volume, showing an association between a swelling ratio of >1.6 and the occurrence of enophthalmos at 6 months.

In our study, we considered 3 anatomic elements involved in the pathophysiology of ocular motility restriction related to orbital floor BOFs. Fracture measurement and quantification methods using RF, MH, and MSS are simple, quick, and open to routine practical use, and they can be carried out in <5 minutes. Previous studies showed their high accuracy, reliability, and reproducibility.[9,10]

The RF was known to be correlated with the degree of enophthalmos during the initial phase of trauma, especially if the bone defect was in the posterior orbital cone.[3,10,22] Contrary to previous studies that showed no association between fracture size and long-term clinical outcome, a significant correlation emerged in our study between RF and the severity of enophthalmos after 6 months, independently of surgical correction.[14,21,22]

Our results also demonstrated a correlation between MH and the persistence of binocular diplopia as well as the severity of the ocular motility restriction. To our knowledge, similar results have not been reported. The prognostic significance of soft tissue herniation was studied by Gilbard et al in 1985, who found a proportional correlation between the amount of herniation and orbital expansion and the risk of developing enophthalmos. However, this association was not found in our results.[12]

On the basis of our results, MSS appeared to be associated with the severity of ocular deviation restriction. The MSS was first developed by Higashino et al[15] as part of a prognostic study in patients with orbital floor fractures conservatively managed. The association between a high MSS score and the development of diplopia and/or enophthalmos 6 months after trauma enabled them to build a treatment algorithm. The MSS also emerged in the study by Schouman et al[10] as the main predictive factor in the treatment decision making process for pure BOF.

The main weakness of our study lies in the small number of patients included, which made it impossible to obtain a high power of statistical analysis. However, the sample size was comparable to, or larger than that of similar studies. Another criticism is that we analyzed data of both surgically and conservatively treated patients. Although this could be considered a deficiency, given that surgery can represent an additional confounding variable which can negatively influence the final outcome, the separate analysis of the 2 subgroups showed similar patterns. For this reason, we decided to analyze both groups together to improve the statistical power.

To our knowledge, this is the first study of its kind to take into account reproducible, validated CT parameters.[9,10] Our description of long-term sequelae included not only persistent clinical disorders, such as diplopia or severe enophthalmos ($\geq$2 mm), but also subclinical disorders detected through a detailed orthoptic examination. We thus included analysis of mild enophthalmos (2 mm) and ocular motility restrictions that were not accompanied by clinical diplopia. This allowed us to improve the detection sensitivity for orthoptic abnormalities by excluding instances of central vision compensation.

Interestingly, all except 1 patient had a simultaneous upward and abduction gaze limitation related to a restriction of passive gliding of the inferior rectus muscle over the fractured orbital floor. This is in contrast with the majority of published reports, which describe only vertical gaze limitations. This discrepancy could be explained by procedural differences. Most investigators tested vertical motility with the eyeballs aligned with the primary visual axis rather than with the orbital axis, which is off to the side by about 23°. These findings emphasize the importance of systematically assessing ocular motility with the patients looking toward the fractured side to eliminate the risk of failing to detect even some minor limitations.

CONCLUSION

Our study showed the significantly predictive value of RF for the occurrence of long-term enophthalmos and of MH for persistent diplopia. Although unable to predict the appearance of ocular motility restriction, MH and MSS were strongly correlated with the severity of ocular deviation limitations. Although promising, these results should be interpreted with caution given the limited number of patients. It is not possible to draw any definitive conclusions, which will hopefully be provided after an ongoing prospective study is completed in our department.

REFERENCES

1. Bartoli D, Fadda MT, Battisti A, et al. Retrospective analysis of 301 patients with orbital floor fracture. *J Craniomaxillofac Surg* 2015;43:244–247
2. Cole P, Boyd V, Banerji S, et al. Comprehensive management of orbital fractures. *Plast Reconstr Surg* 2007;120:57S–63S
3. Whitehouse RW, Batterbury M, Jackson A, et al. Prediction of enophthalmos by computed tomography after “blow out” orbital fracture. *Br J Ophthalmol* 1994;78:618–620
4. Raskin EM, Millman AL, Lubkin V, et al. Prediction of late enophthalmos by volumetric analysis of orbital fractures. *Ophthal Plast Reconstr Surg* 1998;14:19–26
5. Ploder O, Klug C, Voracek M, et al. Evaluation of computer-based area and volume measurement from coronal computed tomography scans in isolated blowout fractures of the orbital floor. *J Oral Maxillofac Surg* 2002;60:1267–1272
6. Tahernia A, Erdmann D, Follmar K, et al. Clinical implications of orbital volume change in the management of isolated and zygomaticomaxillary complex-associated orbital floor injuries. *Plast Reconstr Surg* 2009;123:968–975
7. Kwon J, Barrera JE, Jung T-Y, et al. Measurements of orbital volume change using computed tomography in isolated orbital blowout fractures. *Arch Facial Plast Surg* 2009;11:395–398
8. Neinstein RM, Phillips JH, Forrest CR. Pediatric orbital floor trapdoor fractures: outcomes and CT-based morphologic assessment of the inferior rectus muscle. *J Plast Reconstr Aesthetic Surg* 2012;65:869–874
9. Schouman T, Courvoisier DS, Imholz B, et al. Computational area measurement of orbital floor fractures: reliability, accuracy and rapidity. *Eur J Radiol* 2012;81:2251–2254
10. Schouman T, Courvoisier DS, Van Issum C, et al. Can systematic computed tomographic scan assessment predict treatment decision in pure orbital floor blowout fractures? *J Oral Maxillofac Surg* 2012;70:1627–1632
11. Smith B, Lisman RD, Simonton J, et al. Volkmann’s contracture of the extraocular muscles following blowout fracture. *Plast Reconstr Surg* 1984;74:200–216
12. Gilbard SM, Mafee MF, Lagouros PA, et al. Orbital blowout fractures. The prognostic significance of computed tomography. *Ophthalmology* 1985;92:1523–1528
13. Harris GJ, Garcia GH, Logani SC, et al. Correlation of preoperative computed tomography and postoperative ocular motility in orbital blowout fractures. *Ophthal Plast Reconstr Surg* 2000;16:179–187
14. Matsunaga K, Asamura S, Morotomi T, et al. Association between preoperative inferior rectus muscle swelling and outcomes in orbital blowout fracture. *J Craniomaxillofac Surg* 2011;39:509–514
15. Higashino T, Hirabayashi S, Eguchi T, et al. Straightforward factors for predicting the prognosis of blow-out fractures. *J Craniofac Surg* 2011;22:1210–1214
16. Kunz C, Sigron GR, Jaquiéry C. Functional outcome after non-surgical management of orbital fractures—the bias of decision-making according to size of defect: critical review of 48 patients. *Br J Oral Maxillofac Surg* 2013;51:486–492
17. Cohen J. *Statistical Power Analysis for the Behavioral Sciences. 2nd ed.* Hillsdale, NJ: Lawrence Erlbaum Associates; 1988
18. Tahiri Y, Lee J, Tahiri M, et al. Preoperative diplopia: the most important prognostic factor for diplopia after surgical repair of pure orbital blowout fracture. *J Craniofac Surg* 2010;21:1038–1041
19. Burnstine MA. Clinical recommendations for repair of isolated orbital floor fractures: an evidence-based analysis. *Ophthalmology* 2002;109:1207–1210
20. Kwon JH, Moon JH, Kwon MS, et al. The differences of blowout fracture of the inferior orbital wall between children and adults. *Arch Otolaryngol Head Neck Surg* 2005;131:723–727
21. Kang SJ, Lee KA, Sun H. Swelling of the inferior rectus muscle and enophthalmos in orbital floor fracture. *J Craniofac Surg* 2013;24:687–688
22. Eom T, Kim Y. Analysis of symptoms according to areas of orbital floor in orbital inferior wall fractures. *J Craniofac Surg* 2015;26:647–649