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The “European zygomatic fracture” research project: The epidemiological results from a multicenter European collaboration

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ABSTRACT

Purpose: Fractures of the zygomaticomaxillary complex (ZMC) are common injuries that may lead to loss of an aesthetically pleasing appearance and functional impairment. The aim of this study was to analyze the demographics, causes, characteristics, and outcomes of zygomatic fractures managed at several European departments of oral and maxillofacial surgery.

Materials and methods: This study is based on a multicenter systematic database that allowed the recording of all patients with ZMC fractures between 1 January 2013 and 31 December 2017. The following data were recorded: gender, age, personal medical history, etiology, side of zygomatic fracture, classification of ZMC fracture, associated maxillofacial fractures, symptoms at diagnosis, type of performed treatment, and sequelae/complications.

Results: A total of 1406 patients (1172 males, 234 females) were included in the study. Statistically significant correlations were found between assault-related ZMC fractures and the A3 class ($p < .0000005$) and between Infraorbital Nerve (ION) anesthesia and B class ($p < .00000005$).

Conclusion: The most frequent cause of ZMC fractures was assault, followed by falls. The most frequently involved decade of age was between 20 and 29 years. The decision and type of surgical treatment of ZMC fractures depends on several issues that need to be considered on a case by case basis.

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1. Introduction

Fractures of the zygomaticomaxillary complex (ZMC) are common injuries that may lead to loss of an aesthetically pleasing

appearance and functional impairment (Raschke et al., 2013; van Hout et al., 2016; Gomes et al., 2006). The management of these fractures is controversial, as evidenced by varied and often conflicting treatment philosophies described in the literature (Gomes et al., 2006). In fact, reconstruction of the ZMC still represents a challenge for maxillofacial surgeons because of its important position in facial esthetics and its contribution to facial contour. This is why, among facial fractures, the zygoma is one of the most

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frequently involved bones (Khaqani et al., 2018; Forouzanfar et al., 2013; Calderoni et al., 2011).

The aim of any kind of treatment of ZMC fractures is the reduction of the zygomatic bone and, whenever possible, the re-establishment of the aesthetics and function of the ZMC, with the fewest side effects. The introduction of open reduction and rigid internal fixation using miniplates has led to greater stability and fewer complications, so that the use of miniplates is now state of the art (Calderoni et al., 2011; Haworth et al., 2017). However, despite several publications on the epidemiology, incidence and etiology of zygomatic complex fractures, there remains no consensus agreement regarding diagnosis and management of such challenging injuries (Calderoni et al., 2011; Haworth et al., 2017).

To this aim, an understanding of the demographic patterns of this kind of facial fractures is of importance for prevention and treatment.

Therefore, several European centers that had already shown research experience in maxillofacial trauma decided to collaborate on a research project about zygomatic fracture epidemiology in Europe (Bakardjiev and Pechalova, 2007; Tabaković et al., 2015; Kokemueller et al., 2012; Konstantinović et al., 2010; Merlet et al., 2018; Boffano et al., 2017; Corre et al., 2013; Malanchuk and Kopchak, 2007; Dediol, 2012; Bins et al., 2015; Salentijn et al., 2014a; Salentijn et al., 2014b; Benech et al., 2013; Brucoli et al., 2018a; Brucoli et al., in 2019; Brucoli et al., in 2018b; Arcuri et al., 2012; Brucoli et al., 2005; Saponaro et al., 2009).

The aim of this study was to analyze the demographics, causes, characteristics, and outcomes of zygomatic fractures managed at several European departments of oral and maxillofacial surgery. The results of this collaboration in a multicenter study on maxillofacial trauma epidemiology over a 5-year period are presented here.

2. Material and methods

The present study was conducted at several European departments of oral and maxillofacial surgery: the Division of Maxillofacial Surgery at the University of Eastern Piedmont (Novara, Italy); the Department of Oral and Maxillofacial Surgery/Pathology at the VU University Medical Center and Academic Centre for Dentistry Amsterdam (Amsterdam, The Netherlands); the Department of Maxillofacial Surgery at the University Hospital Dubrava (Zagreb, Croatia); the Clinic of Maxillofacial Surgery of the School of Dentistry at the University of Belgrade (Belgrade, Serbia); the Department of Maxillofacial Surgery at the Medical University (Plovdiv, Bulgaria); the Department for Oral and Maxillofacial Surgery at the Bogomolets National Medical University (Kiev, Ukraine); and the Service de Stomatologie et Chirurgie Maxillo-faciale at the Chu de Nantes (Nantes, France). This study is based on a systematic computer-assisted database that allowed the recording of all patients hospitalized with zygomatic fractures in the involved maxillofacial surgical units across Europe, between 1 January 2013 and 31 December 2017. Criteria for inclusion were unilateral fracture of zygoma (alone or associated with other maxillofacial fractures), and hospital treatment.

The following data were recorded for each patient: gender, age, personal medical history, etiology, side of zygomatic fracture, classification of zygomatic fracture according to Zingg et al. (1992), associated maxillofacial fractures, symptoms at diagnosis, type of performed treatment (reduction without fixation, ORIF), type of osteosynthesis technique (1-point fixation, 2-point fixation, 3-point fixation, 4-point fixation), and sequelae/complications.

The following categories of cause of injury were considered: fall, motor vehicle accident (MVA), assault, sport injury, work injury, and other causes. Zygomatic fractures were determined from computed tomography scans at admission to hospital and classified

according to Zingg et al. (1992) classification: A1 (Isolated fracture of zygomatic arch), A2 (Isolated fracture of lateral orbital wall), A3 (Isolated fracture of inferior orbital rim), B (Involvement of 4 buttresses: “tetrapod fracture”), C (Comminuted fracture).

Associated maxillofacial fractures were classified as follows: Orbital floor, Orbital medial wall, Orbital roof, Nose, Frontal sinus, Le Fort, Mandible.

The following symptoms at diagnosis were recorded: edema, ecchymosis, anesthesia of the ION, diplopia, enophthalmos, exophthalmos.

The type of fixation of zygomatic fracture was further specified according to the site of plating in cases with 1-point-fixation (F, frontozygomatic; M, maxilla-zygomatic; I, infraorbital rim) and in cases with 2-point-fixation (F+M, F+I, M+I).

Finally, the following sequelae and complications were recorded: infection, plate exposure, asymmetry, ION anaesthesia at follow up, diplopia at follow-up, other.

Patient characteristics were analyzed using descriptive statistics. Statistical analysis was used to search for associations among multiple variables. Statistical significance was determined using the χ^2 (van Hout et al., 2016) or Fisher exact test, if the sample sizes were too small. Statistical significance was set at .05.

3. Results

On the whole, 1406 patients (1172 males, 234 females) met the inclusion criteria during the study period (2013–2017) and were included in the study. Of these, 83% were male, whereas 17% were female, with a male to female ratio of 5:1. Mean age was 41.5 years (median, 37; standard deviation, 17.4; range, 5–98). The most frequently involved decade of age was between 20 and 29 years, followed by 30–39 years (Fig. 1). Fig. 2 shows percentages of females and males within each decade, thus highlighting the highest male to female ratios in the first decades and the highest number of female patients in the 80–89 decade (M:F ratio, 1.04:1).

Within the study sample, 592 right ZMC fractures and 814 left ZMC fractures were observed.

Most patients (1076 patients, 76.5%) did not report any habitual smoking, alcohol, and/or drug use, whereas the remaining 330 did (Fig. 3).

As for etiology, the most frequent cause of injury was assault with 537 patients, followed by falls (418 patients), MVAs (200 patients), sport accidents (131 patients), work accidents (48 patients), and other causes (72 patients) (Fig. 4).

As for Zingg et al. (1992) classification, ZMC fractures were grouped as in Table 1. The relationship etiology–classification is depicted in Fig. 5, with the highest percentage of assault-related ZMC fractures among the A3 class, demonstrated also by a statistically significant correlation ($p < .0000005$).

Associated orbital floor fracture was encountered in 217 patients, whereas orbital roof and medial wall fractures were observed in 33

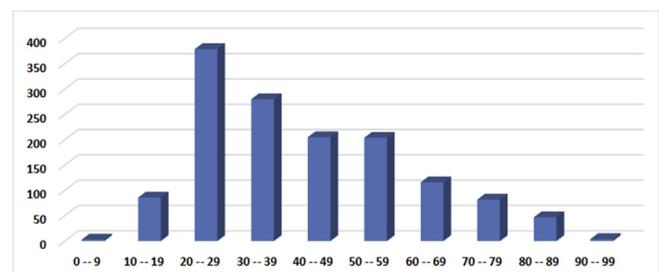


Fig. 1. Decades of age in the study population.

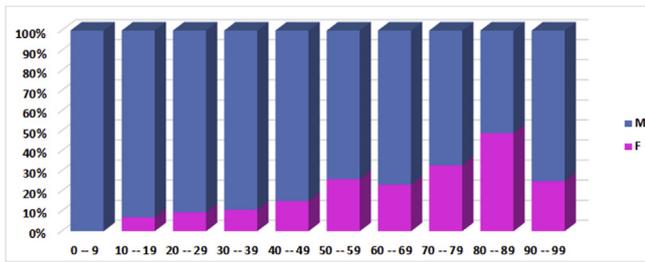


Fig. 2. Percentages of females and males within each decade in the study population.

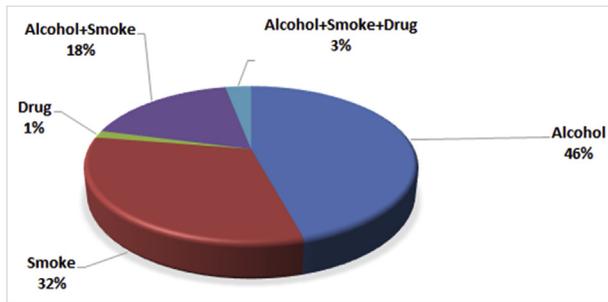


Fig. 3. Habitual smoking, drinking, and/or drug use.

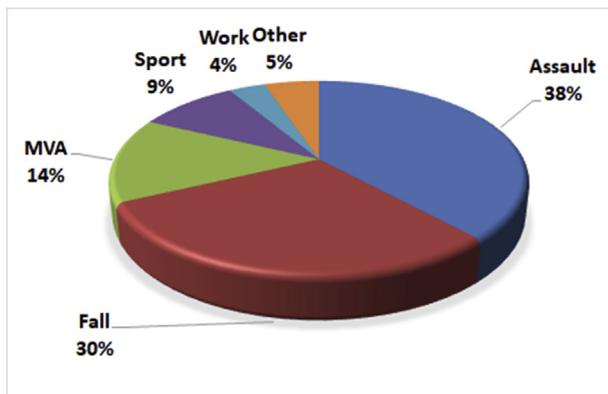


Fig. 4. Etiological factors in the study population.

Table 1
Study population according to Zingg et al. classification.

Classification	Patients
A1	221
A2	24
A3	252
B	820
C	89
Total	1406

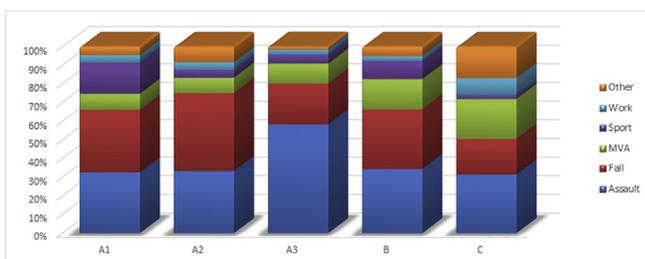


Fig. 5. Etiological factors according to Zingg classes.

and 22 cases, respectively. In addition to orbital fractures, the most frequent associated maxillofacial fracture was nasal fracture (168 patients), followed by mandibular fracture (115 patients), Le Fort (86), and frontal sinus fracture (39 patients). On the whole, 680 associated fractures were observed in 481 patients (Fig. 6), whereas in 925 subjects no associated fractures were present.

Table 2 summarizes the observed symptoms in the study population, with edema and ecchymosis being the most frequent.

In 757 patients (54% of the population), a reduction without ORIF/a conservative treatment was performed, whereas in the remaining 649 cases (46%), an ORIF by 1-point-fixation (264 cases), 2-point-fixation (315 cases), 3-point-fixation (63 cases), or 4-point-fixation (7 cases) was performed.

As for 1-point-fixation group, the most frequent plating site was maxilla-zygomatic (M), followed by infraorbital rim (I), and fronto-zygomatic (F) (Fig. 7). Instead, the plating sites for the 2-point-fixation group are depicted in Fig. 8.

Sequelae and complications were observed in 148 patients, with ION anesthesia being the most frequently observed symptom at follow up (Table 3). Among the 117 patients with ION anesthesia at follow up, 107 already referred such condition at diagnosis of ZMC fracture, whereas among the 4 patients with diplopia at final check, 3 already presented such condition at diagnosis.

A statistically significant correlation was observed between ION anesthesia and B class according to Zingg et al. (1992) classification ($p < .00000005$).

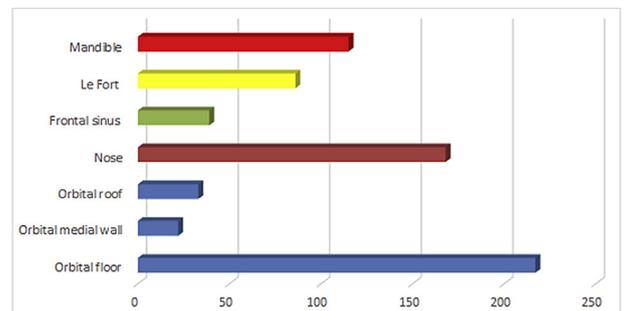


Fig. 6. Associated maxillofacial fractures in the study population.

Table 2
Symptoms and signs at diagnosis within the study population.

Symptoms/Signs	N
Edema	1375
Ecchymosis	1273
Anesthesia of the ION	851
Diplopia	87
Enophthalmos	15
Exophthalmos	11
Total	3612

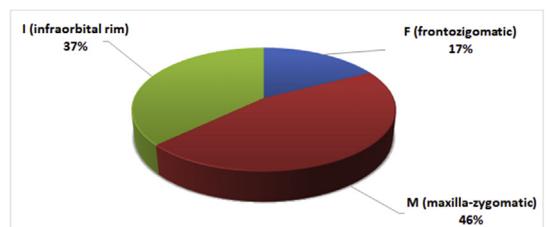


Fig. 7. Percentages of subcategories of 1-point-fixation population.

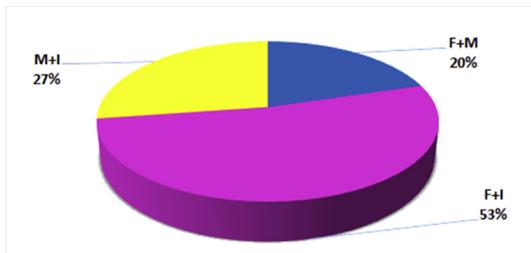


Fig. 8. Percentages of subcategories of 2-point-fixation population (M, maxilla-zygomatic; I, infraorbital rim; F, frontozygomatic).

Table 3
Sequelae and complications at follow up.

	N
Infection	6
Plate exposure	7
Asymmetry	12
ION anesthesia at follow up	117
Diplopia at follow up	4
Other	12

Finally, **Table 4** presents the patient characteristics, treatment and sequelae according to ZMC classification.

4. Discussion

Fractures of the ZMC are common and can lead to loss of an aesthetically pleasing appearance and functional impairment, as the high incidence of these lesions seems to be related to the prominent position of those bones within the facial skeleton. In fact, the zygomatico orbital.

Complex and zygomatic arch present as important structures in facial contour (Raschke et al., 2013; van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018; Forouzanfar et al., 2013).

Of course, epidemiological analyses widely vary with geographic area, population density, socioeconomic status, and type of facility in which the research is conducted (van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018; Forouzanfar et al., 2013; Calderoni et al., 2011). However, the importance of epidemiological studies is confirmed by their implication in the current clinical practice and prevention.

The predominance of male patients that emerge in facial trauma literature (Raschke et al., 2013; van Hout et al., 2016; Gomes et al.,

2006; Khaqani et al., 2018; Forouzanfar et al., 2013; Calderoni et al., 2011; Haworth et al., 2017; Bakardjiev and Pechalova, 2007; Tabaković et al., 2015; Kokemueller et al., 2012; Konstantinović et al., 2010; Merlet et al., 2018; Boffano et al., 2017; Corre et al., 2013; Malanchuk and Kopchak, 2007; Dediol, 2012; Bins et al., 2015; Salentijn et al., 2014a; Salentijn et al., 2014b; Benech et al., 2013; Brucoli et al., 2018; Brucoli et al., in 2019; Brucoli et al., in 2018b; Arcuri et al., 2012; Brucoli et al., 2005) is confirmed by the male to female ratio of 5:1 of our study population. Mean age was 41.5 years with an age range of 5–98 years.

Furthermore, the predominance of involvement within the first decades of age is a common finding in the literature (Raschke et al., 2013; van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018; Forouzanfar et al., 2013). In fact, our results highlighted the highest male to female ratios in the first decades and the highest number of female patients within the 80–89 decade (M:F ratio, 1.04:1). This variation may correlate with the types of activities in which individuals of both genders engage as well as to their age groups (Raschke et al., 2013; van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018; Forouzanfar et al., 2013; Calderoni et al., 2011; Haworth et al., 2017). On the other side, changes taking place during the aging process (such as visual acuity and balance disorders) may be responsible for the growing frequency of falls observed in both genders within the older decades (Gomes et al., 2006; Khaqani et al., 2018; Forouzanfar et al., 2013; Calderoni et al., 2011).

Most patients (1076 patients, 76.5%) did not report any habitual smoking, alcohol, and/or drug use, whereas the remaining 330 did. Alcohol dependency was the most frequently encountered habit.

As for etiology, the most frequent cause of injury was assault with 537 patients, followed by falls and MVAs, thus confirming the current trend of assaults being the most frequent cause of facial trauma (van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018; Forouzanfar et al., 2013).

Regarding Zingg et al. (1992) classification, B type ZMC fractures were the most frequent, followed by A type. Among A type fractures, A1 and A3 were substantially equivalent as groups. The relationship etiology–classification did not show any significant variation, with the only exception being represented by the highest percentage of assault-related ZMC fractures among the A3 class, demonstrated also by a statistically significant correlation ($p < .0000005$).

It was not surprising to observe that a great number of patients also presented with orbital floor fracture and a nasal fracture, which are often associated with the very same impact as the force responsible for ZMC fracture.

Table 4
Patient characteristics, treatment and sequelae according to ZMC classification.

	Zingg et al. ZMC fracture classes			All patients
	A type (n: 497)	B type (n: 820)	C type (n: 89)	
Patient characteristics				
Mean age	38,6	43,2	42,7	41,5
M:F ratio	5,6	4,6	5,8	5
Most frequent aetiology	Assault	Assault	Assault	Assault
Other maxillofacial injuries	110 (22,1%)	323 (39,4%)	48 (53,9%) $p < .0005$	
Treatment of zygoma				
Reduction without fixation	336 (67%)	407 (50%)	14 (16%)	757 (54%)
ORIF	161 (33%)	413 (50%)	75 (84%) $p < .0000005$	649 (46%)
Average n of fixation sites in ORIF cases	1,1	1,9	1,9	1,7
Sequelae				
Presence of sequelae and complications	16 (3%)	116 (14%)	16 (18%)	148

The signs and symptoms seem to have a close relationship with the extent and type of zygomatic injury. Our study indicated that the infraorbital nerve deficit was often encountered in B type ZMC fractures, with a statistical correlation. This may be caused by fracture lines crossing that area and/or damage secondary to an injury or by a bony compression of the nerve at the fracture site as it leaves the infraorbital foramen (Raschke et al., 2013; van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018).

In more than half of the population, a reduction without ORIF/a conservative treatment was performed. For example, all A1 ZMC fractures were treated by a conservative/only reduction option. Instead, in the remaining 46% of cases, an ORIF by 1-point-fixation (264 cases), 2-point-fixation (315 cases), 3-point-fixation (63 cases), or 4-point-fixation (7 cases) was performed. The variability of 1-point-fixation (with the plate placement either on the maxillozygomatic suture, or infraorbital rim, or frontozygomatic suture) and of 2-point-fixation is due to several factors: first of all, the variability of the ZMC fracture with higher displacement in different sites of the tetrapod. Second, a great role is played by the preference of surgeons that is often granted to the maxilla-zygomatic suture in order to avoid cutaneous scars. Third, the stability of the ZMC fracture may often be assessed intraoperatively following the placement of the first plate: according to the obtained stability, a second plate may be avoided or become necessary.

Sequelae and complications were observed in 148 patients, with ION anesthesia being the most frequently observed symptom at follow-up. However, it should be noted that among the 117 patients with ION anesthesia at follow-up, 107 were already referred for such a condition at diagnosis of ZMC fracture, and that among the 4 patients with diplopia at final check, 3 already presented with such a condition at diagnosis. Such results are of the utmost importance, because such undesired events should not be always considered as “complications” but rather as results of the trauma that cannot be always healed. Of course, ION anesthesia is acknowledged to have an unpredictable prognosis, with or without surgery. As for diplopia, surgeons should also remember that it may also depend on post-traumatic neuropathy of III, IV or VI nerves: in this case, surgery may help in recovering facial asymmetry following a ZMC fracture, but it cannot be useful for the improvement of diplopia, which should be managed by ophthalmologist later. The observed correlation between ION anesthesia and B class ($p < .00000005$) confirms that the greater the trauma, the higher the possibility of nerve impairment.

Table 4 provides correlations of some variables in the study population with the classes of ZMC fractures. No significant results were observed as for mean age, M:F ratio or etiology. Instead, as expected, C type (comminuted) fractures were significantly associated with other maxillofacial injuries, probably as a result of a high-energy trauma. Then, A type fractures, as previously mentioned, more frequently underwent reduction without fixation, whereas C type fractures presented the highest percentage of (and a significant association with) ORIF. Finally, B and C type fractures had an average higher number of fixation sites in comparison with A type fractures.

The decision and type of surgical treatment of ZMC fractures depends on several issues to be considered, such as the displacement of the fracture, the age of the patient, associated symptoms, surgeon experience, or the hospital setting. The presence of palpable bony step, bony asymmetry, anaesthesia or paraesthesia to the lip/cheek or side of the nose, and palpable emphysema are all specific features of displaced zygomatico-maxillary fracture. Therefore, patients presenting with these signs are likely to undergo further investigation and possible surgery (Raschke et al., 2013; van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018; Forouzanfar et al., 2013; Calderoni et al., 2011). Nevertheless, there is no consensus on the

employment of the different possible surgical options for ZMC fractures (Calderoni et al., 2011), and probably there will always remain a sort of variability in the management of ZMC fractures on a case by case choice, based on fracture features and patient condition (Raschke et al., 2013; van Hout et al., 2016; Gomes et al., 2006; Khaqani et al., 2018).

Even timing of treatment should be decided on a case by case choice, either as soon as possible or when the post-traumatic swelling has resolved (Raschke et al., 2013).

5. Conclusions

This multicenter study allowed us to analyze a large study population, in order to decrease bias and confounding factors. Our results provide valuable epidemiological information about ZMC fractures in Europe, which is crucial, as management of zygomatic complex fractures still remains a challenging issue and lacks an internationally accepted consensus. Our data may be useful for further studies and contribute towards reaching a consensus opinion on the management of this type of fracture.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

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