Original Article - Retrospective Study

Analysis of Different Safety Devices in the Prevention of Motorcycle-Related Craniofacial Trauma - A Retrospective Study

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Abstract

Introduction: Motorcycle accidents are one of the most frequent causes of trauma. Safety devices and helmets can influence the severity of injuries. Our retrospective study wants to evaluate the different effectiveness of Open-face and Full-face helmets in the prevention of craniofacial trauma. **Materials and Methods:** The sample consists of 440 patients admitted to two Level I Trauma Centres in Northern Italy, between January 2002 and February 2019, because of motorcycle-related craniofacial trauma. For each patient personal data were collected, as well as type and site of fractures, type of helmet, if worn, Comprehensive Facial Injury (CFI) score and Abbreviated Injury Score (AIS-Head) for head injuries. Inferential statistical analysis was then conducted. **Results:** Two hundred and eighty-eight patients wore Open-face helmets (69.7%) and 125 patients wore Full-face ones (30.3%). Mean CFI score (Standard deviation - SD) observed in patients with Open-face helmets was 7.0 (SD: 6.8) and surgery was required in 149 cases (51.7%); while it was 4.9 (SD: 6.0) in patients with Full-face helmets for whom surgery was required in 43 cases (34.4%) ($P < 0.0001$ and $P = 0.002$, respectively). Multivariate analysis shows that severity of facial trauma is a significant risk factor for head injury severity with OR 1.90 (95% confidence interval: 1.43 - 2.51) and $P < 0.0001$. **Discussion:** Full-face helmets are definitely considered to be more protective for facial trauma, which is also a significant risk factor for the severity of head injuries. The type of helmet chosen influences the need of surgical treatment in case of craniofacial trauma.

Keywords: Facial injuries, head protective devices, head trauma, motorcycle, trauma severity indices

Introduction

Motorcycle accidents represent, in many countries, one of the main causes of trauma submitted to the attention of maxillofacial surgeons:[1,2] Bikers are exposed to 30 times greater risk of suffering trauma compared to car drivers.[3]

Safety devices are able to influence the severity of injuries:[4] there are many helmet types available on the market with variable protection profiles [Figure 1].

Aim of this study is to evaluate the effectiveness of different safety devices in motorcycle-related road accidents, focusing on the prevention of craniofacial injuries, measured using comprehensive facial injury (CFI) score[5,6] and abbreviated injury score (AIS-Head) for head injuries.

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Methods

This retrospective observational study enrolled 440 patients with motorcycle-related trauma evaluated between January 2002 and February 2019 by a team of five surgeons experienced in maxillofacial injuries and shared between two Level I Trauma Centers in Northern Italy. Patients of

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any sex and age with motorcycle-related craniofacial trauma, regardless of safety devices used, were included. Patients without thorough clinical and radiological documentation (traditional or computed tomography) were not included, as well as patients with other modalities of injury, without craniofacial involvement or in which the type of helmet used was not declared by the prehospital trauma care team. For each patient, the primary variables, which are type of helmet worn, CFI and AIS-Head scores, calculated by a specialist at the time of the first evaluation of the patient or, if retrospectively calculated by the database officer, verified by comparison with the score attributed by at least two of the five members of the surgical team, were registered. Sex, age, mortality, type, and site of facial fractures, which contribute to the scores calculation, were also recorded and considered as secondary variables. The multiple types of helmet worn at the time of the trauma have been simplified, reducing the possibilities to two main types: "Full-face" (road or cross type) and "open-face" (modular, jet, or demi-jet) helmets.[7] Since the presence of an incorrectly fastened helmet is known to have a greater negative impact than the type of helmet itself, this condition has been considered as the absence of any helmet,[8-11] to avoid any influence on the results.

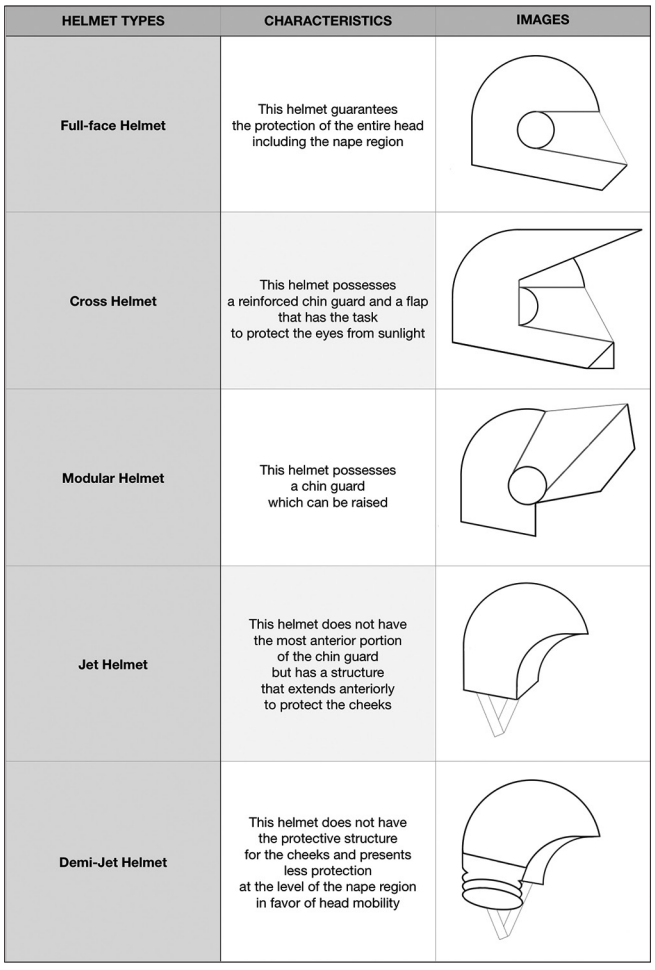

Figure 1: Helmet types available on the market

The population characteristics were described as absolute numbers and percentages in case of dichotomous variables, while continuous parameters were summarized using mean, median, standard deviation, and interquartile range. Inferential statistical analysis was conducted by evaluating the association between the use and type of the helmet and CFI and AIS-head scores, respectively. Multivariate analysis was carried out including the type of helmet, CFI, and AIS-head scores. Statistical analysis was conducted using Stata 9.0 software (Stata Corporation, College Station, Texas, USA).

This research study was conducted retrospectively from data obtained for clinical purposes. We consulted extensively with our Institutional Review Board who determined that our study did not need ethical approval. This study has been conducted in accordance with the ethical principles mentioned in the Declaration of Helsinki (2013).

Results

Sample characteristics are reported in Table 1. A total number of 440 victims of motorcycle-related accidents were consecutively included.

In our sample, 27 patients (6.1%) did not wear helmet while 413 subjects (93.9%) correctly used their own safety device. Among them, 288 subjects wore open-face helmets (69.7%) while 125 patients full-face ones (30.3%).

Sites of injuries were assessed on the basis of bony facial thirds involved, reporting only once patients with more than one fracture of the same facial third.

Twenty-four patients reported fractures of the upper facial third (4.8%): among these ones, 13 patients wore open-face helmets (54.2%), nine patients wore full-face helmets (37.5%) and two patients did not wear any safety device (8.3%).

Three hundred and sixty patients reported fractures of the middle facial third (72.6%); open-face helmet was

Table 1: Sample characteristics: age, sex, type of helmet worn, in patients with correctly fastened helmet, mortality in open-face, full-face, and nonwearing helmet population

Characteristics	Results
Age	
Mean±SD (range)	35.4±13.2 (12-78)
Median (IQR)	34 (25-45)
Males (%)	395 (89.8)
Females (%)	45 (10.2)
Helmet worn (total %)	413 (93.9)
Open-face helmet	288 (69.7)
Full-face helmet	125 (30.3)
Mortality (total %)	24 (5.4)
Open-face helmet	13 (54.2)
Full-face helmet	9 (37.5)
No helmet	2 (8.3)

SD=Standard deviation; IQR=Interquartile range

worn by 232 patients (64.5%), full-face helmet was worn by 102 patients (28.3%), and helmet was not worn by 26 patients (7.2%).

One hundred and twelve patients reported fractures of the lower facial third (22.6%); 84 patients wore open-face helmets (75.0%), 22 patients wore full-face helmets (19.6%), and six patients did not wear any type of helmet (5.4%).

There was also an involvement of soft tissues in 160 patients (36.3%); open-face helmet was worn by 118 patients (73.8%), full-face helmet was worn by 31 patients (19.4%), and helmet was not worn by 11 patients (6.8%).

Table 2 highlights the severity of facial injuries measured with CFI score and the requirement for subsequent surgery in patients wearing open-face and full-face helmets. CFI <4 is considered mild facial trauma, 4≤ CFI <10 is moderate facial trauma, whereas CFI ≥10 is considered severe facial trauma.

Table 3 shows distribution of moderate (0 ≤AIS-Head ≤2) and severe (AIS-Head ≥3) head injuries in patients wearing helmet or not and in the subsets of patients who wore different types of helmet.

Results of a uni- and multivariate analysis between type of helmet and severity of facial trauma in relation to head injury severity outcome are summarized in Table 4. Severity of facial trauma is measured with CFI score while head injury severity with AIS head.

Figure 2 analyses the distribution of head injury severity, through facial injury severity groups, for patients wearing open-face or full-face helmets. CFI <4 is considered mild facial trauma, 4≤ CFI <10 is moderate facial trauma whereas CFI ≥10 is considered severe facial trauma. Moderate head injuries are measured with AIS head ≤2 and severe head injury with AIS head ≥3.

Discussion

Motorcycle trauma represents a consistent proportion of road accident injuries. In our sample, the main users of motorcycles are male (395/440-89.8%) with a mean age of 35.4 years [Table 1].

Mortality rate of motorcycle-related trauma is not so high in our population and overall number of deaths reaches 5.4% (24/440). This is in line with the international literature[12] and reflects both the severity of multidistrictual involvement and the performance of care reached by dedicated Level I Trauma Centers.

In our sample, 6.1% of patients (27/440) did not wear helmet correctly; this is a huge number in a country with strict road safety laws, as Italy has. However, one of the most interesting results of this analysis is that more than two out of three riders use open-face helmets and only one out of three uses full-face ones [Table 1].

A preponderant use of open-face helmets is observed among dead patients (13/24–54.2%), but numbers are too small to be able to perform a conclusive analysis. The proportion of deaths stratified by type of helmet worn shows in fact a greater homogeneity of results (open-face helmet: 13/288–4.5%; Full-face helmet: 9/125–7.2%; No helmet: 2/27–7.4%).

Few scientific studies are reported in literature about the effectiveness of these safety systems, traducing their results through the correlation with measured trauma severity. Most of them analyze the outcome using scores frequently self-limited in their application to craniofacial trauma. Consequently, contradictory results are reported in literature.[7,8,10,11,13-24]

Table 2: Severity of facial injuries measured with comprehensive facial injury score and requirement for subsequent surgery in patients wearing open-face and full-face helmets

	Open-face helmet (%)	Full-face helmet (%)	*P*
CFI <4	102 (35.4)	69 (55.2)	0.001
4≤ CFI <10	121 (42.0)	38 (30.4)	
CFI ≥10	65 (22.6)	18 (14.4)	
Mean CFI±SD (range)	7.0±6.8 (0-39)	4.9±6.0 (0-33)	<0.0001
Median CFI (IQR)	5 (2-9)	3 (1-6)	
Surgery	149 (38.1)	43 (11.0)	0.002
No surgery	126 (32.2)	73 (18.7)	

CFI=Comprehensive facial injury; SD=Standard deviation; IQR=Interquartile range

Table 3: Severity of head injuries measured with abbreviated injury score-Head in patients wearing and nonwearing helmets or using open-face and full-face ones

	No helmet (%)	Helmet (%)	*P*	Open-face (%)	Full-face (%)	*P*
0≤ AIS-head ≤2	11 (40.7)	265 (64.2)	0.014	190 (66.0)	75 (60.0)	0.147
AIS-head ≥3	16 (59.3)	148 (35.8)		98 (34.0)	50 (40.0)	
Mean±SD (range)	2.9±1.4 (0-5)	1.9±1.7 (0-6)	0.004	1.9±1.7 (0-6)	2.1±1.8 (0-6)	0.144
Median (IQR)	3 (2-4)	2 (0-3)		2 (0-3)	2 (0-3)	

AIS=Abbreviated injury score; SD=Standard deviation; IQR=Interquartile range

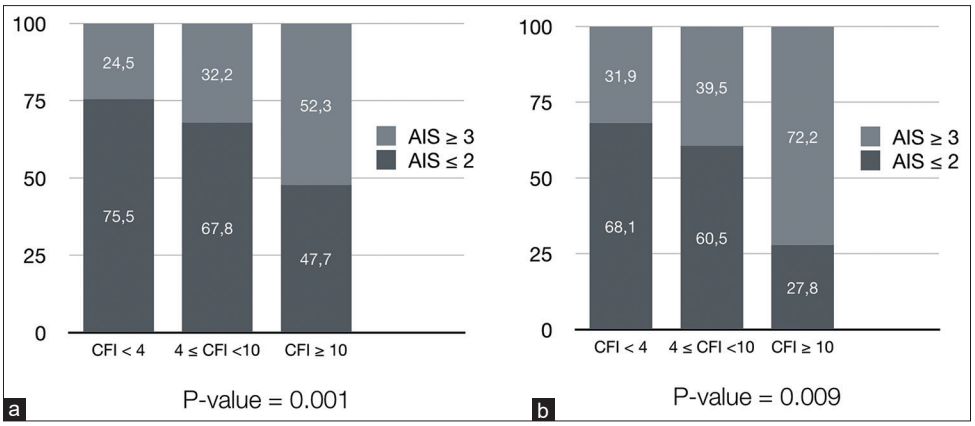

Figure 2: Graphical display of correlation between facial (CFI score) and head (AIS score) injury severity in patients wearing (a)open-face helmets or (b) full-face helmets

Table 4: Uni- and multivariate analysis between type of helmet worn and severity of facial trauma, respect to head injury severity main outcome

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*P*	OR (95% CI)	*P*
CFI	1.78 (1.37-2.32)	<0.0001	1.90 (1.43-2.51)	<0.0001
Helmet type	0.77 (0.50-1.19)	0.245	0.63 (0.40-1.00)	0.050

OR=Odd ratio; CI=Confidence interval; CFI=Comprehensive facial injury

Our study is, therefore, one of the few in which both the impact of different types of helmet and the severity of facial and brain damages are considered using dedicated scores. In this way, we can measure the greater effectiveness of full-face helmets compared to open-face ones in preventing motorcycle-related facial trauma. Furthermore, our sample is one of the widest described in literature.

The distribution of injuries among facial thirds indicates that, in all cases, there is a preponderant involvement of midface, which is characterized by the most prominent structures of the face, such as nasal and zygomatic bones.

A higher frequencies of midfacial fractures are reported in patients who wore open-face helmets compared to the ones wearing full-face helmets (232/360–64.5% vs. 102/360–28.3%). Same tendency is observed with regard to mandibular fractures (84/112–75.0% vs. 22/112–19.6%) and fractures of the upper facial third (13/24–54.2% vs. 9/24–37.5%).

Soft tissue injuries are also found more frequently in riders who did not wear a helmet (11/27–40.7%) or who wore an open-face helmet (118/288–40.9%), compared to patients who wore a full-face helmet (31/125–24.8%); this is especially true for those wounds complicated with nerve, salivary duct or lachrymal drainage system involvement, or with loss of tissue (8.5%).

The most interesting result of our analysis is the increase in severity of facial injuries, objectified using CFI score, for riders who wore an open-face helmet at the time of the trauma: the proportion of patients affected by moderate and severe facial trauma, with CFI score ≥4, among open-face helmet users compared to full-face helmet users is significantly higher [Table 2]. This objectively measured demonstration of the protective role of full-face systems has never been previous reported in literature.

The same principle is similarly highlighted by evaluating the need for surgical treatment of the reported facial lesions, a parameter strongly correlated to the severity of injuries. We can affirm that patients who wore a full-face helmet underwent surgery with a statistically lower rate than those who wore an open-face helmet [Table 2].

More controversial is the evaluation of the overall effect of different types of helmets on the severity of brain injuries: the protective effect of helmets on brain trauma is confirmed, as demonstrated by the higher AIS head scores found in patients without a helmet, but the impact of the different type of helmet does not show a significant difference [Table 3], even in multivariate analysis [Table 4].

Facial trauma severity is a single risk factor (odds ratio = 1.90, $P < 0.0001$) for traumatic brain injury severity [Table 4][25], hence the protective effect of full-face helmets on facial injuries [Table 2] could indirectly reflect on greater safety even in the case of head trauma [Table 4 and Figure 2].

There is a higher rate of severe head injuries with AIS head ≥3 in patients with CFI score ≥10 who wore a full-face helmet compared to patients who wore an open-face one [Figure 2]. This can be explained by considering the high energy required to produce such a severe facial trauma in riders wearing full-face helmets, which is directly reflected in a contextual greater impact on the brain.

Our study has some limitations. Patients were identified retrospectively and, although the sample size is adequate, especially when compared to the literature, it is not big enough to guarantee full statistical significance: authors expect that the greater severity of head injuries assessed by AIS-head score in motorcyclists wearing an open-face helmet will become statistically significant as the sample size increases. Furthermore, it was not possible to identify

precisely the mechanism of injury and the energies involved in the cases presented, limiting the possibility of interpretation of the data. Moreover, in patients who wore a helmet, its fitting was unknown at the time of the trauma: if the helmet is too large, it can move on patient's head or come off in an accident, giving rise to alterations of its protection profile and even causing some types of facial injuries, such as fractures of nasal or zygomatic bones.

Finally, our study only includes patients who, due to a road accident, underwent diagnostic assessment for craniofacial injuries. Consequently, motorcyclists, who were not subjected to medical evaluation as they had not suffered injuries, were not included in this study. Therefore, the real protective effect of using helmets, and in particular full-face ones, is not totally highlighted.

Conclusions

With respect to the objectives, our study allows us to conclude that full-face helmets are definitely considered to be more protective for facial trauma, which is also a significant risk factor for the severity of head injuries. The type of helmet chosen influences the need of surgical treatment in case of craniofacial trauma. Further prospective studies, preferably with larger samples, have to be carried out to further investigate the correlation between facial and brain trauma and the protective effect of full-face helmets on head trauma. These results are intended to be a guide for legislative choices in the field of road safety, given the disabling aesthetic and functional consequences of craniofacial trauma as well as the associated economic burden, including the health and social costs related to any residual disabilities.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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