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Understanding the relevance of comprehensive facial injury (CFI) score: Statistical analysis of overall surgical time and length of stay outcomes☆

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A R T I C L E I N F O

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A B S T R A C T

Comprehensive facial injury (CFI) score is a powerful and extremely simple scale used to grade the clinical severity of all facial injuries, and is expressed in terms of the overall surgical time needed for definitive treatment. Its statistical validation was previously reported in 2019. The aim of this study was to investigate further the link with duration of surgery, applying the score to a larger sample of patients, and to evaluate the relationship between CFI score and other extremely relevant dependent variables: length of stay (LOS) in high care units (HCU) and in intensive care units (ICU).

1406 patients with diagnosis of at least one facial bone fracture, and treated by the same team in two highly specialized trauma centers, were studied. For each patient a specific CFI score is assigned and overall surgical time, length of stay, and presence of associated injuries were recorded. Data were divided into six clusters according to CFI score: (1) 0–5, (2) 6–10, (3) 11–15, (4) 16–20, (5) 21–25, and (6) >25. Regressions between CFI clusters and duration of surgery (minutes), LOS in ICU (days), and in HCU (days) were established. In addition, the presence of associated head and/or somatovisceral injuries was analyzed and related to CFI score.

Statistical analysis confirmed linear regression existing between each CFI cluster and overall surgical time ($p < 0.00001$), with improved significance of the results using median values of surgical duration for each cluster ($p = 0.0001$). It also demonstrated the existence of linear regression between all CFI clusters and LOS in HCU ($p = 0.0001$) and between CFI clusters 3–6 and median values of LOS in ICU ($p = 0.0001$). Finally, associated injuries were observed to be more frequent in high CFI score clusters, occurring in around 90% of patients with a CFI score >25 ($p < 0.00001$). Association of head and facial injuries play a major role in high LOS in ICU values, whereas coexistence of facial, head and somatovisceral involvement increases LOS in ICU to over twice that for single association.

Surgical time and length of stay are outcomes traditionally used to assess the statistical significance of many new proposed trauma score. The strong correlation demonstrated between CFI score and each of these variables confirms its value and reliability.

CFI score is proven to be an ideal, simple, informative, and reproducible tool for measuring severity of facial injuries and their clinical impact. It allows correlation with associated head and somatovisceral injuries, focusing attention on the interesting field of reciprocal influences in simultaneous, multi-districtual involvement. None of the previously proposed facial injury severity scales have offered such informative and statistically significant features.

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1. Introduction

The comprehensive facial injury (CFI) score is a comprehensive and extremely simple scale used to classify the clinical severity of all facial injuries, making it a perfect tool for use by trauma team members (Canzi et al., 2019).

CFI score is expressed in relation to overall surgical time needed for definitive treatment of each type of facial fracture. This is considered to be the best parameter for summarizing the level of commitment of resources because of facial involvement. Surgical duration is only one of the outcomes that can be considered relevant in terms of integrative organizational and management requirements. Length of stay (LOS) in a high care unit (HCU) or in an intensive care unit (ICU) could also be extremely relevant (Moore et al., 2014; Aita et al., 2018; Keller et al., 2019).

The aim of this study was to improve the statistical significance of CFI score in predicting overall surgical time and to evaluate its informative capacity regarding LOS, using a sample of more than 1400 patients treated by the same team in two highly specialized trauma centers.

2. Materials and methods

This study used a case series of patients under a team of five surgeons — experts in the treatment of traumatological maxillofacial lesions — shared by two level-I trauma centers in Italy (Niguarda Hospital in Milan and San Gerardo Hospital in Monza).

The study included 1406 patients with diagnosis of at least one facial bone fracture, comprising 1028 males (73.1%) and 378 females (26.9%) of all ages (mean 39.6 ± 20.4, range 1–90 years). 1050 patients (74.7%) were operated for facial injuries, while 356 patients (25.3%) were subjected to conservative or non-operative management.

Patients without thorough radiological documentation (traditional or CT), with soft tissue lesions treated under local anesthesia or on an outpatient basis, who died before undergoing maxillofacial surgery, or with concomitant non-traumatic specialist pathologies were not included.

The data were collected by retrospective sampling from January 2008 (date of formation of the inter-hospital specialist team) to October 2015 (data collection starting date) and prospective sampling from October 2015 to August 2016 (date of sampling completion).

The individual CFI severity score was calculated for each patient and recorded in a specific database, along with the radiological diagnostic images stored in specific hospital servers (for skeletal injuries), and the clinical or photographic evaluation systematically collected and filed (for soft tissue injuries).

The CFI scale (Fig. 1) works like a checklist, offering an anatomical and functional classification of facial injuries. Anatomical classification divides the facial area into three horizontal thirds: the lower third (including the mandibular symphysis, body, angles, vertical branches, and condyles, as well as the lower dentoalveolar arch); the middle third (including the upper maxilla and upper dentoalveolar arch, zygoma, lateral and medial wall and floor of orbits, and nasal bones); and the upper third (consisting of the orbital roof and frontal bone, and involving the frontal sinus and its drainage system).

Functional distinction results in two alternative scores for each fractured site: a lower score for compound fractures, generally needing conservative treatment or nonoperative management; and a higher score for displaced fractures, for which an open reduction and internal osteosynthesis are needed more frequently, leading to a longer treatment time.

Each site-specific score ranges from 1 to 6 and is reciprocally proportioned according to the estimated a-priori duration of the procedure required for the treatment of each fractured anatomical site.

An additional severity score is applied for comminuted fractures or with loss of substances, such as bony atrophy, which can therefore increase the complexity and duration of the corrective surgery.

Multi-fragmentary Le Fort fractures are assigned to the highest Le Fort level identifiable, eventually with additional comminution points. Unilateral Le Fort fractures are assigned half the numeric value proposed in the CFI chart, so bilateral Le Fort fracture levels could be combined.

In zygomatic complex fracture, an additional orbital-floor score is assigned only if reconstruction is needed; the same applies to nasal bone fracture scores for Le Fort II and III fractures.

Soft tissue injuries are evaluated separately and scores added to that obtained for the three-thirds skeletal injuries: 1 point is assigned for simple and uncomplicated lacerations; 5 points are assigned for large or complicated wounds with nerve, salivary duct, or lachrymal system involvement, loss of tissues, or retrobulbar hematoma.

The database compiler scrolls through the list and gives a partial score based on the combination of injuries reported for each patient, evaluated using radiological server and clinical/photographic documentation.

The final individual score is obtained by adding together the partial results according to the patient's injuries.

For our study, each score obtained was calculated by a specialist at the time of the first evaluation of the patient or, if retrospectively calculated by the database officer, was verified by comparison with the score individually attributed by at least two of the five members of the surgical team. The overall sample was then divided into six clusters according to the range of CFI scores:

Cluster 1: CFI $\leq$ 5
Cluster 2: CFI between 6 and 10
Cluster 3: CFI between 11 and 15
Cluster 4: CFI between 16 and 20
Cluster 5: CFI between 21 and 25
Cluster 6: CFI > 25

Analysis of the computerized clinical documentation also made it possible to record the results of three outcomes:

Outcome 1. Duration (minutes) of the surgical intervention performed for the definitive treatment of the facial injuries of each patient.
Outcome 2. Overall length of stay (days) in high care unit (LOS in HCU).
Outcome 3. Overall length of stay (days) in intensive care unit (LOS in ICU).

Days of hospitalization in a low care unit (general medicine, mental health department, rehabilitation unit, etc.) were excluded because this was influenced more by existing comorbidities than by the severity of traumatic lesions.

The presence of associated head injuries and/or AIS > 3 somatovisceral injuries, classified according to the Abbreviated Injury Scale-98 scoring system (Association for the Advancement of Automotive Medicine — AAAM, 1998), is considered a source of bias that could influence Outcome 3 and scheduled. Patients with at least one day spent in an ICU were divided into four groups:

Group A. Patients with exclusive facial involvement.
Group B. Patients with associated head and facial injuries.

COMPREHENSIVE FACIAL INJURY(CFI) score

Mandible	**c**	**d**
Dentoalveolar	1	2
Body/Angle/Symphysis	1	3
Ramus/Condyle	1*	5*
Tot		
Mid-Face		
Dentoalveolar	1	2
LeFort I	1	4
LeFort II	2	5
LeFort III	4	6
NOE	2	6
Zygoma	2	4
Nasal	1	3
Orbital floor	2	5
Medial wall	1	4
Tot		
Upper face		
Frontal sinus Anterior wall	2	4
Posterior wall/Frontonasal duct	2	6
Orbital roof/rim	2	4
Tot		
Soft tissues	1**	5**
Tot		

Unilateral Le Fort fractures are assigned half the numeric value
Each bone atrophy or fragments comminution upgrade Total Score +3 points

"c" = Not displaced fractures or indication to *Non-Operative Management*
"d" = Displaced fractures that need *Open Reduction and Internal Fixation*
* **Condyle "c"** = intra-articular (displaced or not)
"d" = extra-articular displaced fractures
** **Soft tissue "c"** = Simple laceration, not complicated
"d" = Complicated (i.e. Facial or trigeminal nerve/salivary duct involvement, loss of tissues, human/animal bite, gunshot wound, lachrymal drainage system, retrobulbar hematoma)

Incomplete or greenstick fractures do not increase Total Score

Fig. 1. The CFI scale for estimating the severity of facial trauma.

Table 1
Sample size, outcomes mean (±SD), and median results (95% CI) for each CFI score cluster (*sum rank test; $p < 0.0001$).

	Cluster 1 ($N = 703$)	Cluster 2 ($N = 564$)	Cluster 3 ($N = 79$)	Cluster 4 ($N = 23$)	Cluster 5 ($N = 17$)	Cluster 6 ($N = 20$)
	Mean ± SD; median (95% CI)					
*Duration of surgery (minutes)	71 ± 52	140 ± 81	220 ± 95	397 ± 168	485 ± 173	493 ± 229
	55 (50–60)	125 (120–135)	210 (189–232)	360 (326–427)	430 (330–624)	513 (365–659)
*LOS in HUC (days)	7 ± 10	11 ± 2	20 ± 23	19 ± 12	38 ± 38	32 ± 13
	4 (4–4)	7 (6–7)	12 (8–15)	17 (11–22)	24 (14–49)	31 (23–37)
*LOS in ICU (days)	–	–	–	9 ± 11	14 ± 14	16 ± 10
				7 (0–14)	10 (1–24)	14 (11–20)

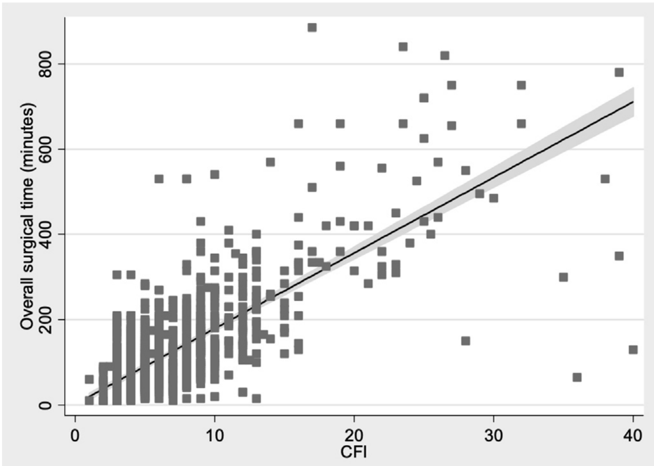

Fig. 2. Linear regression between CFI score and surgical duration (minutes) (ang. coeff. 17.70, R-squared 0.55, 95% CI 16.73–18.68, $p < 0.00001$).

Group C. Patients with somatic or visceral AIS > 3 and facial injuries, but no head involvement.

Group D. Patients with craniofacial and somatovisceral AIS > 3 involvement.

2.1. Statistical analysis

Data for continuous outcomes do not follow a Gaussian distribution so they were summarized, for each cluster, as median values with interquartile ranges, and described by box plots. A non-parametric sum rank test was used to study the association between CFI score and outcomes in term of surgical duration, LOS in HCU, and LOS in ICU; p-values <0.05 were considered significant.

Finally, a model of linear association was studied to predict outcomes for clusters of CFI scores, considering median values of both dependent and independent variables. Data were plotted with 95% CI, and correlation and R-squared coefficients of determination were calculated.

Stata 9.0 software (Stata Corporation, College Station, Texas, USA) was used for the statistical analysis.

3. Results

The mean CFI score assigned was 8.8 ± 4.8; the median value was 4 (CI 3.7–4.3, range 1–40). The median CFI value for operated patients was 5 (CI 4.7–5.3); non-operatively managed patents the value was 2 (CI 1.9–2.1).

198 patients (14% of all cases) required ICU admission for at least 1 day because of head, facial, and/or somatovisceral injuries. 19 patients (9.6%) belonged to Group A (exclusively facial involvement), 39 patients (19.7%) to Group B (head- and facial-associated injuries), 30 patients (15%) to Group C (somatic or visceral AIS > 3 and facial injuries, but no head involvement), and 110 patients (55.7%) to Group D (craniofacial and somatovisceral AIS > 3 involvement).

Sample size, mean and median overall surgical times (patient's who were subjected to conservative management were obviously excluded), LOS in HCU, and LOS in ICU are shown in Table 1.

3.1. Outcome 1, overall surgical time

Fig. 2 shows the results obtained by applying a simple linear regression model (bivariate) on 1050 patients managed surgically, with total CFI score as the independent variable and overall surgical time (minutes) as the dependent variable. The box plot representation helps to highlight the obtained results: a concurrent increase in median surgical time values when the cluster number increased, and pronounced conservation of the interquartile distance amplitude (concerning 50% of the patients belonging to each cluster for each group), at least for CFI scores up to 20 (corresponding with extremely serious and often heterogeneous lesions) (Fig. 3). The rank test carried out on each cluster was irrelevant.

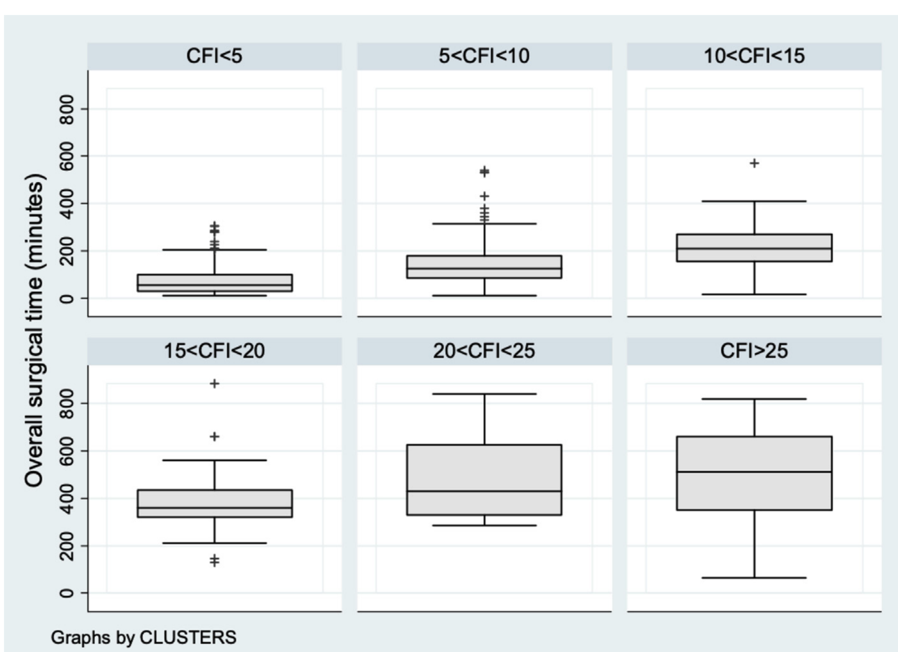

Fig. 3. Box-plot representation of overall surgical time (minutes) for each CFI score cluster ($p = 0.0001$).

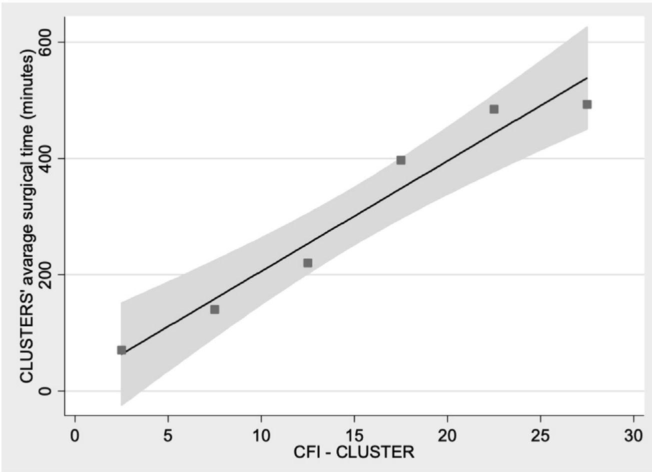

Fig. 4. Linear regression between median values of surgical time and CFI score cluster (ang. coeff. 0.05, R-squared 0.99, 95% CI 0.04–0.06, $p = 0.0001$).

When using median values to describe non-Gaussian results for overall surgical time, for each cluster of CFI scores, the linear association is better represented by reduced 95% CI and an increased R-squared value (Fig. 4).

3.2. Outcome 2, LOS in HCU

A box-plot representation shows an increasing trend for LOS in HCU values (days) with an increase in CFI cluster number (Fig. 5). A rank test demonstrated the statistical significance of the results obtained ($p = 0.0001$).

Using median values of non-Gaussian results for the dependent variable LOS in HCU for increasing CFI cluster number, we confirmed the existence of a linear regression between these two variables, with a satisfactory slope of the line and a high R-squared value (Fig. 6).

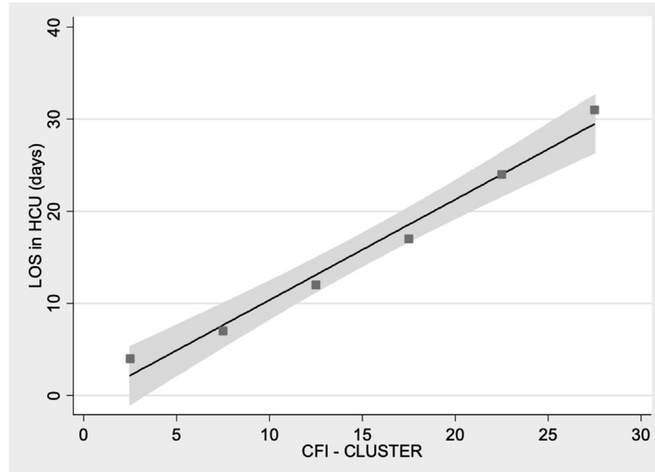

Fig. 6. Linear regression between median values of LOS in HCU (days) and CFI score cluster (ang. coeff. 0.90, R-squared 0.98, 95% CI 0.73–0.070, $p = 0.0001$).

3.3. Outcome 3, LOS in ICU

Fig. 7 shows a box-plot representation of the trend in LOS in ICU values for increasing CFI cluster number. For severe facial injuries (CFI clusters ≥ 3), the median values of the dependent variable increased, as well as the interquartile ranges. A rank test demonstrated the significance of these results ($p = 0.0001$).

Fig. 8 evaluates how the presence of associated AIS > 3 somatovisceral and/or head injuries influenced LOS in ICU for each patient who passed at least 1 day in ICU ($n = 198$ patients, 14.1%).

Fig. 9 analyzes the distribution of coexisting head and somatovisceral injuries for each CFI cluster.

4. Discussion

Comprehensive facial injury score measures clinical severity of facial injuries, correlated with the overall surgical time needed for

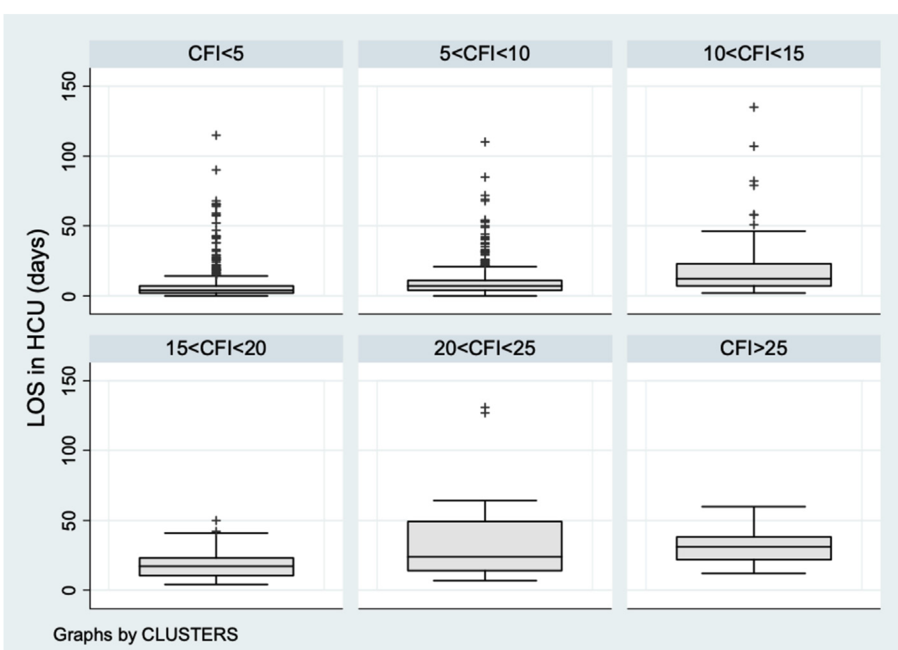

Fig. 5. Box-plot representation of LOS in HCU (days) for each CFI score cluster ($p = 0.0001$).

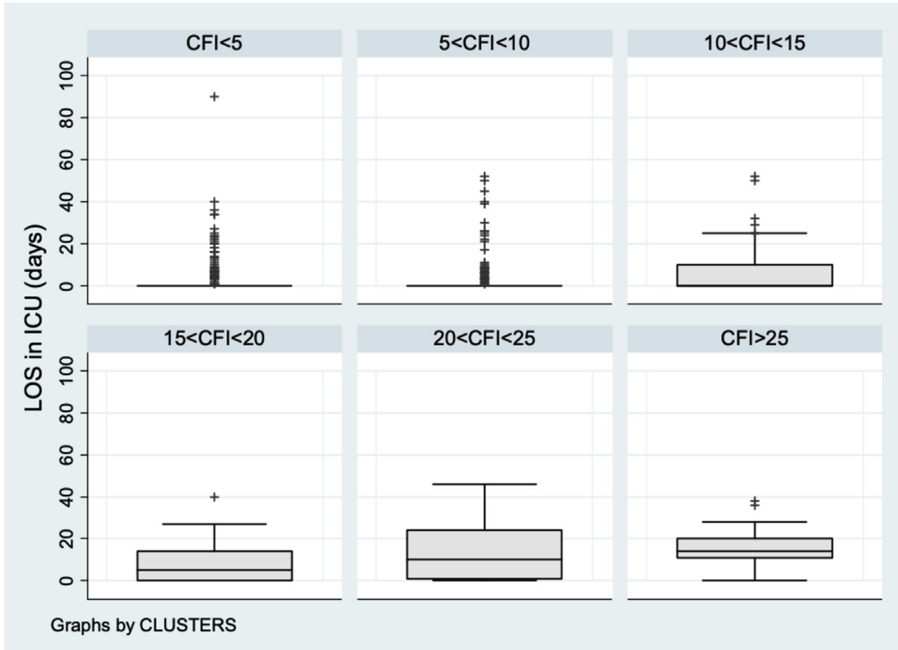

Fig. 7. Box-plot of LOS in ICU (days) for each CFI score cluster ($p = 0.0001$).

definitive treatment of each type of facial fracture (Canzi et al., 2019). The aim of this study was to improve the statistical correlation between CFI and surgical duration, and to demonstrate the wider informative capability of CFI score in terms of other outcomes relevant to the organizational and strategic choices made by trauma teams.

We were able to confirm linear regression existing between CFI score and overall surgical time in a large sample of 1050 patients (Fig. 2). Assignation to a CFI score cluster was deemed more useful for this study, as well as for daily clinical activity, rather than absolute CFI value. This contributed to minimizing possible bias due to interoperator sampling differences. Values for the overall surgical time outcome did not follow a Gaussian distribution, so they were best summarized with median values. Based on these considerations, we demonstrated an improvement in statistical results using median values of surgical duration for each CFI score cluster (Fig. 4).

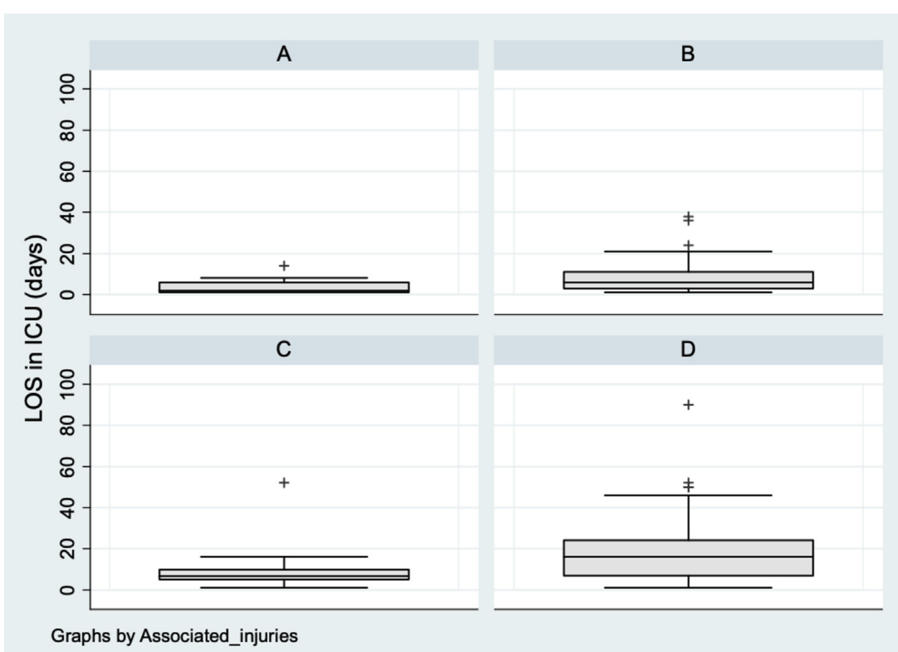

Fig. 8. Box-plot representation of LOS in ICU (days) for each combination of associated injuries ($p = 0.0001$). A = exclusively facial injuries; B = head and facial injuries; C = facial and AIS > 3 somatovisceral injuries; D = facial, head, and AIS > 3 somatovisceral injuries.

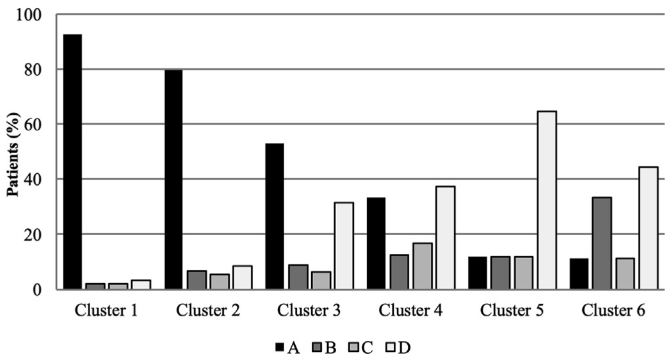

Fig. 9. Associated injuries for each CFI score cluster ($p < 0.00001$). A = exclusively facial injuries; B = head and facial injuries; C = facial and AIS > 3 somatovisceral injuries. D = facial, head, and AIS > 3 somatovisceral injuries.

In line with previous studies, patients of all age and gender were included in this study (Bagheri et al., 2006; Zhang et al., 2006; Zhaohui et al., 2008; Catapano et al., 2010; Canzi et al., 2019).

CFI score originated from the facial injury severity scale (FISS) proposed by Bagheri in 2006, and which was able to correlate with OR charges required to treat facial injuries and with LOS (Bagheri et al., 2006). At the time, FISS was identified as the best available communication tool for multidisciplinary teams (Ramalingam, 2015; Sahni, 2016). Recently, Aita et al. demonstrated FISS's predictive ability regarding length of stay and the likelihood of undergoing specialist surgery (Aita et al., 2018). However, this score remains extremely simplistic, and high scores are needed to reach positive predictive values, for example with extensive injuries involving multiple facial areas.

Maxillofacial injury severity scores (MFISS), proposed by Zhang in 2006 and Zhaohui in 2008, were validated as models able to correlate with treatment costs and LOS. But the choice of an economic outcome makes results not comparable and not reproducible in different socioeconomic/healthcare systems (Zhang et al., 2006; Zhaohui et al., 2008).

In line with our study, Nishimoto et al. tested the clinical and statistical significance of the mandible injury severity score (MISS), proposed by Shetty in 2007, demonstrating its validity in quantifying mandibular trauma severity by the existence of a positive correlation between MISS value, overall surgical time, and LOS (Nishimoto et al., 2019; Shetty et al., 2007).

We presumed that in complex facial trauma cases LOS in ICU could be a relevant adjunctive outcome, so we split total LOS in two distinct dependent variables: LOS in ICU and LOS in HCU.

Our study demonstrated the existence of linear regression between LOS in HCU and CFI score, with high statistical significance ($p = 0.0001$) (Figs. 5 and 6). Validation of this outcome contributes to increasing the informative power of CFI in grading facial injury severity, in terms of commitment of resources.

Linear regression is demonstrated also between CFI clusters ≥ 3 and median values of LOS in ICU ($p = 0.0001$). Severe facial traumas are associated with multiply injured patients; LOS in HCU is the dependent variable that could most be influenced by other injuries, so their presence was analyzed and related to CFI score. High LOS in ICU values was observed in patients with associated injuries, which are more frequent in high CFI clusters (Fig. 9), occurring in around 90% of patients with a CFI score over 25 ($p < 0.00001$). Association of head and facial injuries plays a major role in LOS values, while coexistence of facial, head, and somatovisceral involvement increases LOS in ICU to over twice the values for single associations. Evaluation of coexisting injuries in this study is obviously simplified — a better characterization would require prospective and multicentric samples.

The validation of a model in which the dependent variables were expressed in terms of surgical duration and LOS required a large sample and a reduced number of participating surgeons. The Maxillofacial Surgery Unit shared by Grande Ospedale Metropolitano Niguarda in Milan and Ospedale San Gerardo in Monza represented the perfect context, because the analysis of data referred to only five experienced surgeons, shared between two level-I trauma centers with a wide range of cases.

The main statistical limitation of this study was the heterogeneity of the sampling (retrospective analysis from January 2008 to October 2015 and subsequently prospective until August 2016). The model was based on the analysis of radiological data and the clinical analysis (or photographic documentation) of soft tissue injuries. Thus, this approach allowed an overlapping of outcomes collected at different times and relating to different workers, limiting the effectiveness of the prospective or retrospective sampling.

5. Conclusions

Overall surgical time and length of stay are outcomes traditionally used to assess the statistical significance proposed trauma scores. There is a strong correlation between CFI score and these variables, confirming the reliability and informative value of CFI score.

CFI score is therefore proposed as a powerful, simple, informative, and reproducible tool for evaluating and communicating about facial trauma, both between maxillofacial surgeons from different centers and within multidisciplinary teams. It can express the severity of facial injuries in relation to resource commitment, and its correlation with widespread and reproducible outcomes allows benchmarking analysis of the results.

Creation of a comprehensive and easy-to-use scale for measuring severity of facial trauma allows a deeper understanding of the effects of associated and concomitant injuries, and introduces future research to the interesting field of reciprocal influences in simultaneous multidistrectual injury.

None of the previously proposed facial injury severity scales has demonstrated concurrently such highly informative and statistically significant features.

Declarations of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcms.2019.07.005.

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