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Mechanism, injury patterns, and clinical burden of multiple craniomaxillofacial fractures: a retrospective study

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Research Article

Keywords: Craniomaxillofacial fracture, Facial trauma, Emergency department, Traumatic brain injury, Intracranial hemorrhage, Injury mechanism, Triage, Retrospective cohort study

Posted Date: August 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10493748/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Craniomaxillofacial (CMF) fractures frequently co-occur with other injuries, but predictors, clinical management and outcomes of multiple CMF fracture patterns are incompletely described.

Methods

This retrospective cohort study included adults (≥ 18 years) with radiologically confirmed CMF fractures presenting with Emergency Severity Index (ESI) 2–5 to a Swiss tertiary emergency department (1 January 2019–31 December 2020). Life-threatening conditions (ESI 1) and patients without informed general consent were excluded. Fractures were classified by AO CMF Level 1 regions and grouped as single versus multiple CMF fractures. Multiple CMF were investigated by regression models adjusted for age, sex, alcohol intoxication, and Charlson Comorbidity Index (< 4/≥4).

Results

Among 345 patients, 162 (47.0%) sustained multiple CMF fractures. Multiple fractures were independently associated with traffic accidents (adjusted OR 1.9, 95% CI 1.1–3.4) and falls from height (adjusted OR 3.4, 95% CI 1.2–10.3) and were less likely after tripping (adjusted OR 0.5, 95% CI 0.3–0.9). Monocle hematoma (OR 3.4, 95% CI 2.0–5.8) and malocclusion (OR 3.5, 95% CI 1.5–8.4) were strong clinical predictors of multiple fractures. Patients with multiple fractures had higher rates of intracranial hemorrhage (11.1% vs 4.9%; adjusted OR 2.3, 95% CI 1.01–5.4) and upper extremity injuries (14.8% vs 5.5%; adjusted OR 2.9, 95% CI 1.3–6.4), as well as longer length of hospital stay (adjusted mean difference 3.0 days, 95% CI 2.1–3.9).

Conclusions

Multiple CMF fracture patterns were common, particularly after traffic accidents and falls from height, and were associated with intracranial hemorrhage, upper extremity injuries, higher operative rates, and longer hospital stay.

Background

In Switzerland, approximately 250,000 occupational and 550,000 leisure accidents are reported each year by persons insured under the Accident Insurance Act [1]. Falls are the leading cause of occupational accidents, while sports injuries predominate in leisure settings. Head and neck injuries account for nearly 20% of occupational accidents [1]. Traumatic brain injury (TBI) presents symptoms ranging from headache and dizziness to severe neurological impairment. Moderate to severe TBI may involve

persistent neurological deficits, increased rate of complications and prolonged loss of consciousness [2–4]. Emergency department (ED) patients with head trauma are evaluated for CT imaging based on established criteria such as the Canadian CT Head Rules [5]. Craniomaxillofacial (CMF) trauma presents with pain, swelling, bleeding, sensory deficits, and may cause functional complications including airway compromise or visual disturbance [6]. In Switzerland, facial injuries represent 14.7% of occupational and 7.2% of leisure accidents [1]. Risk factors for maxillofacial trauma include traffic accidents without protective devices, male sex, age 20–39 years, and substance abuse [7–9].

Combined TBI and CMF trauma are common, accounting for nearly half of head injuries in Europe [10]. Despite this, current guidelines typically address TBI and CMF trauma separately, although their co-existence significantly influences outcomes [5, 11–13]. Accurate diagnosis relies on thorough clinical assessment and high-resolution CT imaging, while timely surgical management is critical to prevent long-term functional and aesthetic impairment [14–16]. The AO ("Arbeitsgemeinschaft für Osteosynthsefragen") CMF classification system categorizes fractures by anatomical region and complexity [11, 12, 17]. The classification of the AO divides fractures at level 1 into the mandible, midface, skull base, and cranial vault. A detailed description is provided elsewhere [17]. Most patients have a single simple fracture, but multiple fracture patterns are common in trauma care and remain insufficiently studied [18]. Limited data exist regarding the causes, risk factors, and outcomes associated specifically with multiple CMF fractures [8, 18–21] and in combination with a TBI [22–24]. Therefore, this study investigated the frequency, associated injuries, risk factors, clinical management and outcomes of ED patients with single versus multiple CMF fractures, particularly in the context of concomitant TBI.

Methods

Study design

This retrospective study was performed to identify all patients with CMF fractures who presented from January 1st, 2019, to December 31st, 2020, to the ED of a tertiary care hospital with a large catchment area including 24/7 CMF care in Switzerland. Patients were triaged by using the Emergency Severity Index (ESI) [25] and those triaged with an ESI 2–5 and presenting with a CMF fracture were included in the analysis. Patients under 18 years and all patients with a life-threatening condition who were triaged into the shock room (ESI 1) were excluded because they were treated by trauma specialists and not by emergency medicine physicians. As this was a retrospective cohort study with consecutive inclusion of ED patients, no formal sample size calculation was performed. Only patients who had given general consent for their data to be used for research purposes were included. This study is conducted in accordance with the STROBE guidelines for observational cohort studies. The study was approved by the local ethic committee (BASEC N° Req-2021-01135).

Endpoints

The primary outcome was the presence of concomitant traumatic injuries outside the CMF region during the index ED visit or admission, including intracranial hemorrhage and injuries to the cervical spine, thorax, abdomen, or extremities. The secondary endpoints were the differences in mechanisms of injury, clinical predictors, examinations during the index ED visit, treatments and outcomes between patients with simple and multiple head and face fracture patterns.

Data collection

All ED patients with ESI 2–5 who had a suspected or discharge diagnosis of CMF injuries between January 1st, 2019, and December 31st, 2020, were identified from the clinical information system, and their data were extracted into a single database. After removal of duplicate records and patients without general consent, data were collected from electronic medical records and radiology reports using a predefined protocol. Demographics, comorbidities, injury mechanism, clinical presentation, imaging, associated non-CMF injuries, management, and outcomes were recorded. Injury severity and comorbidity burden were assessed using Injury Severity Score (ISS) and Charlson Comorbidity Index (CCI), respectively. Participants were then divided into two groups (single- or multiple fractures). CMF fractures were classified into three anatomical regions: lower third, middle third, and upper third (Skull Base + Cranial Vault) according to the AO CMF fracture Level One classification [11]. The lower third comprised mandibular fractures. The middle third included fractures of the maxilla, orbit, nose, naso-orbito-ethmoid region, zygomatic arch, zygomaticomaxillary complex, as well as Le Fort fractures (Types I, II, and III). [26] The upper third encompassed fractures of the skull, skull base (fronto- laterobasal fractures and frontal sinus fracture [27, 28]. A detailed description is provided elsewhere [17]. Multiple fractures referred to the presence of more than one fracture across any of these regions. Assessed variables were stratified according to single or multiple fractures.

Statistical analysis

We analyzed the distribution of variables using means and standard deviation (SD) for normally distributed data, and medians and interquartile ranges (IQR) for skewed data. We tested dataset for normality with the Kolmogorow-Smirnow test. Categorical data were presented as frequency.

We used the regression model to analyse the association between the dependent variable and more independent variables by estimating probabilities. For this, the primary (concomitant injuries) and all other secondary endpoints were compared between groups (patients with single vs. multiple fractures) using univariate and multivariable linear as well as logistic regression models. The multivariable model was adjusted for a priori defined and known potential confounders such as age, sex, being under alcohol and Charlson Co-morbidity index (< 4/≥4). For all results, we reported point estimates, 95% confidence intervals and p-values The proportion of missing data was low for all covariates; especially there were no missing data in the primary and secondary endpoints. Therefore, statistical analyses were conducted using complete datasets. The statistical significance was defined as $p < 0.05$. We performed statistical analyses using the statistical program STATA SE (version 18, Stata Corp., College Station, Texas).

Artificial intelligence: Claude, Opus 4.8, Anthropic was used for language editing only. All scientific content, analyses, and interpretations were produced and verified by the authors.

Preregistration: This study was not preregistered, and no prespecified analysis plan was registered prior to data collection.

Results

Patient characteristics

In this retrospective study conducted at a tertiary care center over a two-year period, 793 patients were initially screened based on the inclusion criteria. After excluding 448 patients according to the exclusion criteria, 345 patients were finally enrolled in the analysis: 183 patients (53%) had a single fracture whereas 162 patients (47%) had multiple fractures. The overall mean age was 52 years (SD 23); 119 patients (34.0%) were female, and 78.8% had a Charlson Co-Morbidity Index (CCI) below four. Patients with multiple and single fractures were similar in age (51 years [SD 22]) vs. 52.5 years [SD 24] and had low comorbidity burdens (Table 1). Co-morbidities in detail are presented in Additional file 1.

Table 1
Baseline characteristics and ED presentation

Age, mean (SD)	**All N = 345**	**Single fracture N = 183**	**Multiple fractures N = 162**
	52 (23)	**52.5 (24)**	**51 (22)**
Sex ratio (M:F)	1.9:1	1.6:1	2.4:1
Charlson index ≥ 4	73 (21.1)	46 (25.1)	27 (16.7)
ESI 2	38 (11.0)	18 (9.8)	20 (12.4)
ESI 3	271 (78.6)	137 (74.9)	134 (82.7)
ESI 4	36 (10.4)	28 (15.3)	8 (4.9)
Alcohol intoxication	71 (20.6)	29 (15.9)	42 (25.9)

Values within parentheses are percentages (%) unless otherwise specified. ED = Emergency Department; ESI = Emergency Severity Index. SD = Standard Deviation

Most of the patients (41.7%) presented during the ED mid-shift (from 1 p.m. to 11 p.m.), were mostly admitted by paramedics (59.1%) and were triaged with an ESI level of 3 (78.6%). One in five patients (20.6%) was alcohol intoxicated when presented to the ED (Table 1). Patients with multiple fractures were more likely to be admitted by emergency services (67.3%) than patients with single fractures (51.9%) and consequently less often presented by self-admission (32.7% vs. 48.1%). Alcohol intoxication

was more frequently reported in the group with multiple fractures (25.9% vs. 15.9%) (Table 1), while drug use was uncommon and comparable in both groups (3.3% vs. 3.7%).

Mechanism of injury

The most common cause of accident was fall by tripping (43.2%) followed by traffic accident (18.8%), assault (17.1%) and fall from a bicycle (13.9%). The number of reported electric scooters (4.9%) was low. Regarding injury mechanisms, patients with multiple fractures were more frequently injured by bicycle accidents (16.7%) than patients with single fracture (11.5%), falls from height (12.9% vs. 3.8%), or assault (17.9% vs. 16.4%). In contrast, tripping was a more common cause in patients with single fractures (49.2% vs. 36.4%) (Table 2). After adjusting for confounders, a significantly higher risk of multiple fractures was associated with traffic accidents (adj. OR 1.9, 95% CI: 1.1–3.4, p = 0.030), falls from height (adj. OR 3.4, 95% CI: 1.2–10.3, p = 0.026), whereas the risk was significantly reduced in patients of falls due to tripping (adj. OR 0.5, 95% CI: 0.3–0.9, p = 0.016). No significant association was found for falls from bicycles (adj OR 1.5, 95% CI: 0.8–2.9, p = 0.19) (Table 2).

Table 2
Accident mechanisms

Tripping	**All N = 345**	**Single fracture N = 183**	**Multiple fractures N = 162**	**Unadjusted OR (95% CI)**	**p-value**	**Adjusted OR (95% CI)**	**p-value**
	149 (43.2)	**90 (49.2)**	**59 (36.4)**	**0.6 (0.4–0.9)**	**0.017**	**0.5 (0.3–0.9)**	**0.016**
Traffic accident	65 (18.8)	26 (14.2)	39 (24.1)	1.9 (1.1–3.3)	0.021	1.9 (1.1–3.4)	0.030
Assault	59 (17.1)	30 (16.4)	29 (17.9)	1.1 (0.6–1.9)	0.71	1.0 (0.5–1.9)	0.997
Bicycle accident	48 (13.9)	21 (11.5)	27 (16.7)	1.5 (0.8–2.8)	0.17	1.5 (0.8–2.9)	0.19
Sport accident	32 (9.2)	21 (11.4)	11 (6.7)	0.6 (0.2–1.4)	0.23	0.7 (0.3–1.8)	0.48
Fall from height	28 (8.1)	7 (3.8)	21 (12.9)	3.4 (1.2–9.6)	0.023	3.4 (1.2–10.3)	0.026
Hit by an object	24 (7.0)	14 (7.7)	10 (6.2)	0.8 (0.3–1.8)	0.59	0.8 (0.3–2.0)	0.68
Syncope	17 (4.9)	12 (6.6)	5 (3.1)	0.5 (0.2–1.3)	0.15	0.5 (0.2–1.5)	0.21

Values within parentheses are percentages (%) unless otherwise specified. Adjusted for age, sex, alcohol intoxication, and Charlson Comorbidity Index. Patients may have suffered from multiple mechanisms.

Clinical presentation

Almost all ED patients (91.6%) presented with pain as a leading symptom followed by wounds (53.3%), face swelling/edema (41.5%) and monocle hematoma (29.9%) (Table 3). Adjusted for confounders, several clinical symptoms were significantly associated with multiple fractures. These included monocle hematoma (OR = 3.4, 95% CI: 2.0–5.8, p < 0.001), malocclusion (OR = 3.5, 95% CI: 1.5–8.4, p = 0.005), dental avulsion (OR = 4.1, 95% CI: 1.3–13.0, p = 0.017), swelling (OR = 2.1, 95% CI: 1.4–3.3, p = 0.001), and paresthesia (OR = 2.5, 95% CI: 1.3–4.6, p = 0.005). In contrast, nasal swelling was negatively associated with multiple fractures (OR = 0.4, 95% CI: 0.3–0.8, p = 0.003). On the other hand, no significant association between multiple fractures and wounds (OR = 1.3, 95% CI: 0.8–2.0, p = 0.28) and facial hematoma (OR = 1.3, 95% CI: 0.8–2.3, p = 0.29) was observed (Table 3; Additional file 2).

Table 3
Clinical predictors of multiple fractures at ED presentation

	All N = 345	**Single fracture N = 183**	**Multiple fractures N = 162**	**Unadjusted OR (95% CI)**	**p-value**	**Adjusted OR (95% CI)**	**p-value**
Pain	**316 (91.6)**	**166 (90.7)**	**150 (92.6)**	**1.3 (0.6–2.7)**	**0.53**	**1.2 (0.6–2.7)**	**0.60**
Wounds	184 (53.3)	91 (49.7)	93 (57.4)	1.4 (0.9–2.1)	0.15	1.3 (0.8–2.0)	0.28
Swelling / edema	143 (41.5)	60 (32.8)	83 (51.2)	2.2 (1.4–3.3)	0.001	2.1 (1.4–3.3)	0.001
Monocle hematoma	103 (29.9)	35 (19.1)	68 (42.0)	3.1 (1.9–4.9)	< 0.001	3.4 (2.0–5.8)	< 0.001
Swelling of the nose	84 (24.4)	58 (31.7)	26 (16.1)	0.4 (0.2–0.7)	0.001	0.4 (0.3–0.8)	0.003
Facial hematoma	68 (19.7)	33 (18.0)	35 (21.6)	1.3 (0.7–2.1)	0.41	1.3 (0.8–2.3)	0.29
Epistaxis	60 (17.4)	28 (15.3)	32 (19.8)	1.4 (0.8–2.4)	0.28	1.5 (0.8–2.6)	0.18
Paresthesia CN V	52 (15.1)	17 (9.3)	35 (21.6)	2.7 (1.4–5.0)	0.002	2.5 (1.3–4.6)	0.005
Malocclusion	29 (8.4)	8 (4.4)	21 (13.0)	3.3 (1.4–7.6)	0.006	3.5 (1.5–8.4)	0.005
Dental Avulsion	18 (5.2)	4 (2.2)	14 (8.6)	4.2 (1.4–13.1)	0.013	4.1 (1.3–13.0)	0.017

Values within parentheses are percentages (%) unless otherwise specified. Adjusted for age, sex, alcohol intoxication, and Charlson Comorbidity Index. ED = Emergency Department; CN V = Cranial Nerve V. Patients may have presented with one or more symptoms.

Imaging

More than three quarters of patients (78.8%) received a cranial CT including the facial skeleton. Additional examined regions were the cervical spine (39.1%). Less patients received a full body CT (13.9%). Cranial CT, including facial bone imaging, was the most frequently used diagnostic tool in both groups (78.7% vs. 79%). Interestingly, cervical spine CT scans were less frequent in the multiple fracture group (36.4% vs. 41.5%), whereas polytrauma CT scans were used more frequently in case of multiple fractures (21.6% vs. 7.1%).

Head and facial injury patterns, further injuries and treatment management

Most of the patients had face fractures in the middle third (75.9%), followed by the lower third (18.3%) and upper third (12.2%). Middle third fractures were the most prevalent in both groups (77.6% vs. 74.1%), while mandibular fractures (24.7% vs. 12.6%) and fractures of the upper facial third (24.7% vs. 1.2%) were more common in patients with multiple fractures (Additional file 3). The most common associated injuries were facial wounds (54.5%) and dental trauma (13.9%). In contrast, globe injury was relatively rare (2.9%) (Additional file 3). Patients with single fractures were generally less likely to sustain additional injuries. While patients with multiple fractures had higher rates of upper extremity injuries (14.8% vs. 5.5%) traumatic brain bleeding (11.1% vs. 4.9%), spinal injuries (4.3% vs.1.6%), thoracic injuries (3.7% vs. 0%), and lower extremity injuries (2.5% vs. 0%). TBI (OR 2.3 (95% CI 1.01–5.4, p = 0.047)) and injuries of the upper extremity (OR 2.9 (95% CI 1.3–6.4, p = 0.007)) were significantly associated with multiple fractures. No abdominal injury was reported (Table 4). Focusing on all patients, almost every second patient (46.7%) needed wound care in local anesthesia, 12.8% of patients required dental treatment and 10.4% underwent surgery for further injuries (Additional file 4). Compared with patients with single fractures, those with multiple fractures required more frequently surgical management (62.4% vs 32.2%; adjusted OR 4.0, 95% CI 2.5–6.5; p < 0.001) (Table 4), consultation by CMF specialist (28.4% vs 18.6%; adjusted OR 1.7, 95% CI 1.0–2.9; p = 0.036), and operative treatment of additional injuries (19.1% vs 2.7%; adjusted OR 8.4, 95% CI 3.1–22.3; p < 0.001) (Table 4).

Table 4
Further injuries and treatment management

Upper extremity injury	All N = 345	Single fracture N = 183	Multiple fractures N = 162	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
	34 (9.9)	**10 (5.5)**	**24 (14.8)**	**3.0 (1.4–6.5)**	**0.005**	**2.9 (1.3–6.4)**	**0.007**
Intracranial hemorrhage	27 (7.8)	9 (4.9)	18 (11.1)	2.4 (1.1–5.5)	0.037	2.3 (1.01–5.4)	0.047
Spinal injury	10 (2.9)	3 (1.6)	7 (4.3)	2.7 (0.7–10.7)	0.15	2.9 (0.7–11.6)	0.14
Thoracic injury	6 (1.7)	0 (0)	6 (3.7)	-	-	-	-
Lower extremity injury	4 (1.2)	0 (0)	4 (2.5)	-	-	-	-
Abdominal injury	0 (0)	0 (0)	0 (0)	-	-	-	-
Treatment							
Any surgery	160 (46.4)	59 (32.2)	101 (62.4)	3.5 (2.2–5.4)	< 0.001	4.0 (2.5–6.5)	< 0.001
CMF consultation	80 (23.2)	34 (18.6)	46 (28.4)	1.7 (1.0–2.9)	0.032	1.7 (1.0–2.9)	0.036
Surgery for other injuries	36 (10.4)	5 (2.7)	31 (19.1)	8.4 (3.2–22.2)	< 0.001	8.4 (3.1–22.3)	< 0.001

Values within parentheses are percentages (%) unless otherwise specified. Results are adjusted for potential confounders such as age, sex, being under alcohol and Charlson Co-morbidity index; if less than five events occur, no adjusted regression analysis was performed. ED = Emergency Department; CMF= Cranio-Maxillofacial Surgeon.

Outcomes

In total 253 patients (73.3%) were admitted to the hospital and stayed in median for three days (IQR 0–6). Seven patients (2.0%) were transferred from the ED to the intensive care unit (ICU) for further stabilization and therapy. ICU admission rates did not differ between groups (1.1% vs 3.1%) (Table 5). In-hospital mortality was 0%. Hospital admission was significantly more often (87.7% vs 60.7%; adjusted OR 5.2, 95% CI 2.9–9.3; $p < 0.001$) and the length of hospital stay was also significantly longer (adjusted mean difference 3.0 days, 95% CI 2.1–3.9; $p < 0.001$) in the multiple-fracture group compared to patients with single fractures. Nearly all patients (96.2%) had an ISS < 16; however, patients with multiple fractures had a significantly higher median ISS than those with single fractures (5 [IQR 4–8] vs 1 [IQR 1–4]; adjusted difference 3.7, 95% CI 2.9–4.4; $p < 0.001$).

Table 5
Outcome

Hospital admission	All N = 345	Single fracture N = 183	Multiple fractures N = 162	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
	253 (73.3)	**111 (60.7)**	**142 (87.7)**	**4.6 (2.6–8.0)**	**< 0.001**	**5.2 (2.9–9.3)**	**< 0.001**
Transfer to special care unit	11 (3.2)	3 (1.6)	8 (4.9)	3.1 (0.8–12.0)	0.097	3.1 (0.8–12.1)	0.11
ICU admission	7 (2.0)	2 (1.1)	5 (3.1)	2.9 (0.6–15.1)	0.21	2.8 (0.5–15.3)	0.24
				Unadjusted difference (95% CI)		Adjusted difference (95% CI)	
Length of hospital stay (days) [a]	3 (0–6)	2 (0–4)	5 (3–8)	2.8 (1.8–3.7)	< 0.001	3.0 (2.1–3.9)	< 0.001
Injury severity score[a]	4 (1–5)	1 (1–4)	5 (4–8)	3.7 (3.0–4.4)	< 0.001	3.7 (2.9–4.4)	< 0.001
< 16	332 (96.2)	180 (98.4)	152 (93.8)	-	-	-	-
≥ 16	13 (3.8)	3 (1.6)	10 (6.2)	-	-	-	-

Values within parentheses are percentages (%) unless otherwise specified. Results are adjusted for potential confounders such as age, sex, being under alcohol and Charlson Co-morbidity index; if less than five events occur, no adjusted regression analysis was performed. ED = Emergency Department; CMF = Cranio-Maxillofacial Surgeon. [a]Median (Interquartile range)

Discussion

In this two-year, single-center study at a Swiss tertiary ED, nearly half of CMF-trauma patients had multiple fractures — most after high-energy mechanisms such as traffic accidents and falls from height. At first ED presentation, following symptoms raised significantly the risk of a multiple fracture pattern: monocle hematoma, malocclusion, dental avulsion, and diffuse facial swelling. These patients had more frequent accompanying severe injuries (e.g. intracranial hemorrhage), higher ISS scores, requiring more often surgical interventions and increased hospital admission. Taken together, these findings argue for mechanism- and symptom-guided triage that anticipates complex CMF patterns and prioritizes early surgical interventions.

Associated injuries: intracranial hemorrhage and multiple fractures

A main finding in this current study is the significantly elevated risk of intracranial hemorrhage in patients with multiple CMF fractures. This association is well-documented, with reported rates of concomitant traumatic brain injury ranging from 30% to 70% in patients with facial fractures [4, 10, 29, 30]. Current clinical practice guidelines typically address traumatic brain injury and CMF trauma separately, despite their frequent co-existence and synergistic impact on outcomes [13, 29–31]. The present study reinforces the need for integrated assessment and management protocols that recognize facial fractures as markers of potential intracranial injury.

Upper extremity injuries and polytrauma patterns

Patients with multiple CMF fractures showed in the current study nearly threefold higher risk of upper extremity injury than those with isolated fractures. This reflects the biomechanics of high-energy trauma, where protective reflexes lead to simultaneous facial and upper extremity impact [32]. In this context, recent studies confirm that whole body CT detects unsuspected injuries and alters management in a substantial proportion of trauma patients, in particular those with extremity and facial injuries, and is especially valuable when physical examination is unreliable or multiple injuries are suspected [33–35]. Furthermore, a tertiary assessment, especially of the extremities, is required and recommended to avoid any fractures or further injuries.

Injury mechanisms and multiple fracture patterns

In this study, traffic accidents and falls from height were independent predictors of multiple CMF fractures, while tripping was protective. These findings align with prior research demonstrating that high-energy mechanisms produce more complex fracture patterns. Lu et al. reported that falls from height and traffic accidents resulted in multiple fractures in 88.6% and 73.3% of cases, respectively [36]. The protective effect of low-energy mechanisms such as tripping likely reflects lower force transmission and more localized impact patterns [18]. Alcohol intoxication showed a trend toward association with multiple fractures, consistent with literature linking substance use to higher-energy trauma and more severe injury patterns [32, 37].

Clinical predictors of multiple fractures

Several clinical examination findings emerged as strong predictors of multiple CMF fractures. Monocle hematoma and malocclusion were the most powerful clinical indicators, along with dental avulsion, facial swelling, and paresthesia for multiple facial fractures. The literature has supported these findings that specific physical examination findings predict multiple facial fractures [38–40]. Monocle hematoma indicates periorbital trauma with likely orbital involvement, which frequently occurs in complex midface fracture pattern [41, 42]. Malocclusion is a well-established indicator of mandibular or midface fractures requiring surgical intervention [38, 42, 43]. The high specificity and positive predictive value of these

clinical signs suggest they should prompt comprehensive imaging evaluation and early specialist consultation [39, 42].

Surgical management and healthcare resource utilization

Patients with multiple CMF fractures demonstrated substantially higher rates of surgical intervention and prolonged hospital stays. These findings align with prior studies and show that multiple fracture patterns require more extensive surgical reconstruction and longer recovery periods [44–46]. The increased resource utilization reflects both the technical complexity of managing multiple fracture sites and the higher prevalence of associated injuries requiring multidisciplinary care [31, 47, 48]. It is important to note that the higher ISS in the group with multiple fractures suggests that these patients represent a more severely injured population and also require intensive care resources as well as a longer rehabilitation period [31, 49].

Clinical implications

The identification of specific clinical predictors — particularly monocle hematoma, malocclusion, dental avulsion, and facial swelling — can facilitate early risk stratification for complex fracture patterns and guide imaging decisions. Early recognition of multiple fracture patterns should prompt multidisciplinary consultation involving emergency physicians, oral and maxillofacial surgery, neurosurgery, ophthalmology, and trauma surgery teams. The high prevalence of intracranial hemorrhage and upper extremity injuries in patients with multiple CMF fractures supports the need for whole-body CT protocols in this population, particularly when high-energy mechanisms are involved. Furthermore, a tertiary trauma survey is recommended to identify injuries and fractures of extremities.

Strengths and limitations

This study benefits from consecutive patient sampling over two years, standardized AO CMF fracture classification, and multivariable regression analyses. Potential sources of bias were systematically considered: selection bias may have arisen from the exclusion of ESI-1 and pediatric patients, limiting applicability to the most critically injured and younger populations. Information bias was minimized using a standardized data abstraction protocol, though retrospective chart review may still introduce misclassification. Potential confounding was addressed through multivariable regression analysis adjusting for potential confounders. However, the retrospective single-center design may limit generalizability, and the absence of long-term outcome data precludes assessment of functional recovery. Nevertheless, multiple facial fractures and injuries pose a challenge for regional hospitals and must therefore be treated at trauma and facial surgery centers; consequently, this single-center approach will cover the majority of complex facial injuries. The study period overlapped with the COVID-19 pandemic (2019–2020), which may have altered injury patterns and healthcare utilization. Future prospective multicenter studies with longer follow-up would provide additional insights.

Conclusions

Multiple CMF fracture patterns were common after high-speed trauma or height and associated with intracranial hemorrhage, upper extremity injuries, higher operative rates, increased hospital admission rate and longer length of hospital stay. Mechanism and clinical presentation at ED arrival may assist in risk stratification for complex fracture patterns, supporting early specialist involvement and comprehensive imaging. Integrated approaches addressing CMF trauma and brain injury together may improve patient care and the outcome.

Abbreviations

AO
Arbeitsgemeinschaft für Osteosynthesefragen
CCI
Charlson Comorbidity Index
CI
Confidence interval
CMF
Craniomaxillofacial
CN V
Cranial nerve V
CT
Computed tomography
ED
Emergency department
ESI
Emergency Severity Index
ICU
Intensive care unit
IQR
Interquartile range
ISS
Injury Severity Score
OR
Odds ratio
SD
Standard deviation
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
TBI
Traumatic brain injury

Declarations

Ethics approval and consent to participate

The study was approved by the Cantonal Ethics Committee Zurich (BASEC No. Req-2021-01135) in accordance with the Declaration of Helsinki. Only patients who had given general consent for their data to be used for research purposes were included.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Authors' information

Not applicable.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Author Contribution

Authors' contributionsConceptualization: V.D, K.S; Data curation: V.D, G.L; Statistical analysis: K.S; Interpretation/Investigation: V.D, K.S; Methodology: V.D, K.S; Supervision: K.S; Writing – original draft: V.D, K.S; Writing – review & editing: D.I.K, K.S.

Acknowledgement

The authors thank the emergency department staff and the cranio-maxillofacial surgery team for their clinical support. No professional medical writing assistance was used.

Availability of data and materials

De-identified participant data that underline the results reported in this article will be made available upon reasonable request to the corresponding author, subject to institutional approvals and applicable data protection regulations.

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