Available online at www.sciencedirect.com

ScienceDirect

British Journal of Oral and Maxillofacial Surgery 62 (2024) 704–709

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Concomitant head or neck injury increases risk of traumatic brain injury in facial fracture patients

L. Kokko [a,*], J. Snäll [b,c], T. Puolakkainen [b,c], A. Piippo-Karjalainen [d], A. Suominen [e], H. Thorén [a]

[a] Department of Oral and Maxillofacial Surgery, University of Turku, Lemminkäisenkatu 2, 20520 Turku, Finland
[b] Department of Oral and Maxillofacial Diseases, University of Helsinki, Haartmaninkatu 1, PL 41, 00014 Helsingin Yliopisto, Helsinki, Finland
[c] Helsinki University Hospital, Haartmaninkatu 4, PL 320, 00029, HUS, Helsinki, Finland
[d] Department of Neurosurgery, University of Helsinki and Helsinki University Hospital, Haartmaninkatu 4, PL 320, 00029, HUS, Helsinki, Finland
[e] Department of Community Dentistry, University of Turku, Lemminkäisenkatu 2, 20520 Turku, Finland

Accepted 24 April 2024
Available online 30 April 2024

Abstract

Concomitant traumatic brain injury (TBI) is common in facial fracture patients and prompt intervention is crucially important to minimise the risk of potential long-term sequalae. In order to achieve rapid diagnosis, clinicians need to be aware of the risk factors associated with concomitant TBI and facial fractures. Previous literature suggests that a facial fracture can be considered a significant indicator of TBI. Nevertheless, a large data gap remains on specific injury patterns of facial fractures and associated TBI. Therefore, the objective of this study was to estimate and compare the frequency of and risk factors for TBI in patients with and without different types of additional injuries. The retrospective cohort study included 1836 facial fracture patients aged at least 18 years. The outcome variable was TBI with radiological findings in computed tomography or magnetic resonance imaging. The primary predictor variables were associated injury outside the head and neck, associated cranial fracture and associated neck injury. Based on this study, associated cranial fracture increased the risk of TBI 4.7-fold. Patients with associated neck injury had a 2.1-fold risk of TBI. In addition, significant predictors for TBI were increasing age ($p = 0.0004$), high energy of injury ($p < 0.0001$) and anticoagulant medication ($p = 0.0003$). Facial fracture patients with associated injuries in the head and neck region are at significant risk of TBI. In clinical work, multiprofessional evaluation of facial fracture patients should be routine and repeated survey should be targeted especially at high-risk patients to identify TBIs.

Keywords: Facial fracture; Facial injury; Maxillofacial trauma; Traumatic brain injury; Concomitant injury

Introduction

Traumatic brain injury (TBI), listed by the World Health Organization (WHO) as a major cause of death and disability[1] affects more than 50 million people annually, resulting in significant socioeconomic burden globally.[2] Defined as ‘an alteration in brain function, or other evidence of brain pathology, caused by external force’, TBI often has significant long-term sequalae.[3]

In recent years there has been a change in the epidemiological patterns of TBI. With falls having overtaken road traffic accidents as the most common cause of TBI in Europe, the age of people injured with TBI is on the rise.[4,5] As the population progressively ages in high-income country settings, a similar rise in the proportion of elderly patients has been seen in the facial fracture population.[6-8]

To improve the prognosis of patients who have sustained a TBI, early diagnosis is critically important. Rapid intervention, such as reversing anti-coagulation, is essential to minimise the potential for long-term complications such as morbidity or death. We have previously observed that 15% of facial fracture patients sustain a TBI and that elderly patients have over twice the odds for TBI compared with younger adults.[9] Existing literature suggests that the possibility of TBI should always be considered when encountering a

* Corresponding author at: Lemminkäisenkatu 2, 20520 Turku, Finland.
E-mail address: llekok@utu.fi (L. Kokko).

https://doi.org/10.1016/j.bjoms.2024.04.011
0266-4356/

facial fracture patient. Previous studies reveal that a facial fracture can be considered a significant indicator of TBI.[10] Nevertheless, a large data gap remains on specific injury patterns of facial fractures and associated TBI. In addition, any association between other concomitant injuries and TBI in facial fracture patients remains under studied.

Overall, associated injuries (AIs) are fairly common in facial fracture patients. It can be hypothesised that facial fracture patients with AIs in the head and neck region are more prone to sustaining a TBI when compared with patients sustaining AIs outside the head and neck region or patients without AIs. The aim of this study was to report on the occurrence of TBI in patients with facial fractures. The specific aims were to: 1) estimate and compare the frequency of TBI in patients with and without different types of AIs and, 2) identify risk factors associated with TBI in facial fracture patients. It was hypothesised that TBIs are more common when associated injuries in the head and neck region are present and that different predisposing factors for TBI would be found in facial fracture patients.

Material and methods

Study design and sample

A retrospective cohort study on patients with mandibular and/or midfacial fractures admitted to a tertiary trauma centre (Töölö Trauma Centre of Helsinki University Hospital, Helsinki, Finland) between 2013 and 2018 was conducted. Included were patients who were at least 18 years old and who had undergone computed tomography (CT) or magnetic resonance imaging (MRI) of the brain. Excluded were patients who had solely upper facial fractures (such as fractures of the frontal sinus, superior orbital rim, or orbital roof).

Study variables

The primary outcome variable was TBI with radiological finding in CT/MRI. Cases presenting mild TBI (mTBI) without radiological findings were excluded.

The primary predictor variables were AI outside the head and neck, associated cranial fracture, and associated neck injury. AIs outside the head and neck included injuries of the upper- and lower extremities, chest, pelvis, spine (excluding cervical spine), and abdomen. Associated cranial fracture was defined as fractures of the skull, skull base, and the upper facial third. Associated neck injuries included the cervical spine, blunt cervical vessel, and laryngeal injuries. Wounds and other superficial soft tissue injuries were excluded.

The controlled variables were grouped into the following categories: sex, age, energy of injury, type of facial fracture and anticoagulant therapy. Energy of injury was categorised high when injuries were caused by road traffic accidents, falls from over three metres, or defined as industrial injuries.[11] Type of facial fracture was classified as exclusively midfacial, exclusively mandibular, or combined fracture (such as mandibular + midfacial fractures).

Ethics approval

The study protocol was approved by the Internal Review Board of the Head and Neck Centre of the Helsinki University Hospital, Helsinki, Finland (HUS/356/2017). The Helsinki Declaration guidelines were followed.

Data analysis

Descriptive statistics were calculated for all variables. Associations between controlled variables and primary predictors and between controlled variables and outcomes were determined with the Pearson chi squared test. The Wilcoxon test was used to analyse continuous variables. Risk ratios with 95% confidence intervals were calculated between outcomes and predictors. Univariate logistic regression analysis was conducted to determine the association between outcomes and each primary predictor variable. Variables included in the multivariate model were selected based on statistical significance in the univariate analyses or clinical significance. The interactions between predictors and controlled variables were evaluated and included in the model when $p < 0.05$. The statistical significance was accepted as $p < 0.05$. Statistical analysis used SAS version 9.4.

Results

In total 1836 patients were identified for the study. TBIs were detected in 365 patients (19.9%), including intracerebral haemorrhages, subarachnoid haemorrhages, subdural hematomas, epidural hematomas, and diffuse axonal injuries.

Table 1 presents the descriptive statistics for the 1836 patients. The majority of patients were male (69.7%). The mean (range) age of patients was 50.6 (18.0-102.5) years. Most injuries were caused by other than a high energy mechanism (83.2%). Exclusively midfacial fracture was by far the most common type of facial fracture (74.7%). AI was detected in 34.9% of the patients. AI outside the head and neck occurred in 16.1% of patients. Associated cranial fracture occurred in 15.1% and associated neck injury in 5.7%. In all, 12.9% of the patients had anticoagulant medication prior to injury.

Associations between controlled variables and primary predictors are shown in Table 2. The variables sex ($p = 0.0006$) and energy of injury ($p < 0.0001$) were statistically associated with AI outside the head and neck region. There were significant associations between associated cranial fracture and the variables sex ($p < 0.0001$), energy of injury ($p < 0.0001$), and type of facial fracture ($p < 0.0001$). The variables age ($p = 0.0083$), energy of injury ($p < 0.0001$), and type of facial fracture ($p = 0.0020$) were statistically associated with concomitant neck injury.

The associations between controlled variables and TBI are summarised in Table 3. Significantly associated with TBI were variables age ($p < 0.0001$), energy of injury ($p < 0.0001$), type of facial fracture ($p < 0.0001$) and the use of anticoagulant medication ($p < 0.0001$).

Table 1
Descriptive statistics of 1836 patients with facial fractures. Data are No. (%) unless otherwise stated.

Variable	Patients
Sex	
Male	1280 (69.7)
Female	556 (30.3)
Age (years) mean (range)	50.6 (18.0-102.5)
Energy of injury high*	309 (16.8)
Type of facial fracture:	
Exclusively midfacial	1371 (74.7)
Exclusively mandibular	360 (19.6)
Combined mandibular and midfacial	105 (5.7)
AI	641 (34.9)
AI outside the head and neck**	295 (16.1)
Associated cranial fracture***	278 (15.1)
Associated neck injury****	104 (5.7)
Anticoagulant therapy	236 (12.9)
Traumatic brain injury (TBI)	365 (19.9)

Abbreviations: AI = associated injury.
* Road traffic-related injuries, falls from over 3 metres, and industrial injuries were classified as high-energy traumas.
** including upper- and lower extremity, chest, pelvic, spine (excluding cervical spine), and abdominal injuries.
*** including fractures of the skull, skull base, and the upper facial third.
**** including cervical spine, blunt vessel, and laryngeal injuries.

Table 4 shows the risk analysis between primary predictors and TBI. Associated cranial fracture increased the risk of TBI 4.7 times when compared with patients without associated cranial fracture (95% CI 4.0 to 5.5, p < 0.0001). Patients with associated neck injury had a 2.1-fold risk of TBI as compared when neck injury was absent (95% CI 1.6 to 2.7, <0.0001). Presence or absence of AI outside the head and neck was not significantly associated with the risk of TBI.

Table 5 summarises the unadjusted and adjusted logistic regression analyses for TBI. After adjusting for covariates significantly associated with each primary predictor, patients with associated cranial fracture were at least 10 times more likely to have TBI (OR 10.2, 95% CI 7.4 to 14.0, p < 0.0001). Associated neck injury increased the odds for TBI almost three times (OR 2.8, 95% CI 1.9 to 4.3, p < 0.0001). Patients with AI outside the head and neck had a decreased odds for TBI (OR 0.6, 95% CI 0.4 to 0.8, p = 0.0029).

Table 6 summarises the multivariate logistic regression analysis for TBI. Significant predictors for TBI were associated cranial fracture (OR 10.7, 95% CI, 7.6 to 14.9, p < 0.0001), increasing age (p = 0.0004), high-energy of injury (OR 2.5, 95% CI 1.8 to 3.5, p < 0.0001), and the use of anticoagulant medication (OR 2.1, 95% CI 1.4 to 3.3, p = 0.0003). In addition, patients with exclusively midfacial fractures (OR 1.9, 95% CI 1.3 to 3.0) and those with combined midfacial and mandibular fracture (OR, 2.9, 95% CI 1.5 to 5.4) had greater odds for TBI than patients with exclusively mandibular fractures (p = 0.0015). Associated neck injury seemed to increase the odds for TBI but the association remained statistically non-significant (OR 1.6, 95% CI 0.9 to 2.6).

Table 2
Controlled variables by primary predictors. Data are No. (%).

Variable	AI outside the head and neck present (n=295)	AI outside the head and neck absent (n=1541)	p value	Associated cranial fracture present (n=278)	Associated cranial fracture absent (1558)	p value	Associated neck injury present (n=104)	Associated neck injury absent (n=1732)	p value
Sex:			0.0006**			<0.0001*			0.2273**
Male	181 (61.4)	1099 (71.3)		225 (80.9)	1055 (67.7)		78 (75.0)	1202 (69.4)	
Female	114 (38.6)	442 (28.7)		53 (19.1)	503 (32.3)		26 (25.0)	530 (30.6)	
Age, mean (years)	52.7	50.2	0.0625***	50.7	50.7	0.6158**	55.7	50.3	0.0083***
Energy of injury high*	101 (34.2)	208 (13.5)	<0.0001**	101 (36.3)	208 (13.4)	<0.0001*	39 (37.5)	270 (15.6)	<0.0001**
Type of facial fracture:			0.1100**			<0.0001*			0.0020**
Exclusively midfacial	228 (77.3)	1143 (74.2)		237 (85.3)	1134 (72.8)		82 (78.8)	1289 (74.4)	
Exclusively mandibular	46 (15.6)	314 (20.4)		25 (9.0)	335 (21.5)		10 (9.6)	350 (20.2)	
Combined mandibular and midfacial	21 (7.1)	84 (5.5)		16 (5.8)	89 (5.7)		12 (11.5)	93 (5.4)	
Anticoagulant therapy	41 (13.9)	195 (12.7)	0.5586**	30 (10.8)	206 (13.2)	0.0246**	19 (18.3)	217 (12.5)	0.0894**

Abbreviations: AI = associated injury.
* Road traffic-related injuries, falls from over 3 metres, and industrial injuries were classified as high-energy traumas.
** chi squared test.
*** Wilcoxon test.

Table 3
Controlled variables by traumatic brain injury (TBI). Data are No. (%).

Variable	TBI present	TBI absent	p value
All patients	365 (19.9)	1471 (80.1)	
Sex:			0.4813**
Male (n=1280)	260 (20.3)	1020 (79.7)	
Female (n=556)	105 (18.9)	451 (81.1)	
Age, mean (years)	55.0	49. 5	<0.0001***
Energy of injuryhigh* (n=309)	122 (39.5)	187 (60.5)	<0.0001**
Type of facial fracture:			<0.0001**
Exclusively midfacial (n=1317)	307 (22.4)	1064 (77.6)	
Exclusively mandibular (n=360)	31 (8.6)	329 (91.4)	
Combined mandibular and midfacial (n=105)	27 (25.7)	78 (74.3)	
Anticoagulant therapy(n=236)	70 (29.7)	166 (70.3)	<0.0001**

* Road traffic-related injuries, falls from over 3 metres, and industrial injuries were classified as high-energy traumas
** chi squared test
*** Wilcoxon test

Table 4
Calculation of risk ratio (RR) by traumatic brain injury (TBI) between primary predictor present or absent. Data are No. (%).

Variable	TBI present (n = 365)	TBI absent (n=1471)	Total (n = 1836)	RR (95% CI)	p value
AI outside the head and neck:				0.9 (0.7 to 1.2)	0.5640
Present	55 (15.1)	240 (16.3)	295 (16.1)		
Absent	310 (84.9)	1231 (83.7)	1541 (83.9)		
Associated cranial fracture:				4.7(4.0 to 5.5)	<0.0001
Present	166 (45.5)	112 (7.6)	278 (15.1)		
Absent	199 (54.5)	1359 (92.4)	1558 (84.9)		
Associated neck injury:				2.1(1.6 to 2.7)	<0.0001
Present	41 (11.2)	63 (4.2)	104 (5.7)		
Absent	324 (88.8)	1408 (95.7)	1732 (94.3)		

Abbreviations: AI = associated injury, CI = confidence interval.

Table 5
Unadjusted and adjusted logistic regression analysis for traumatic brain injury (TBI) and primary predictors.

Variable	TBI OR (95% CI)	p value
Unadjusted:		
AI outside the head and neck	0.9 (0.7 to 1.3)	0.5616
Associated cranial fracture	10.1 (7.6 to 13.4)	<0.0001
Associated neck injury	2.8 (1.9 to 4.3)	<0.0001
Adjusted:		
AI outside the head and neck*	0.6 (0.4 to 0.8)	0.0029
Associated cranial fracture **	10.2 (7.4 to 14.0)	<0.0001
Associated neck injury ***	2.8 (1.9 to 4.3)	<0.0001

Abbreviations: AI = associated injury, CI = confidence interval.
* adjusted for covariates significantly ($p < 0.005$) associated with TBI and AI outside the head and neck.
** adjusted for covariates significantly ($p < 0.005$) associated with TBI and associated cranial injury.
*** adjusted for covariates significantly ($p < 0.005$) associated with TBI and associated neck injury.

Discussion

The present study aimed to estimate the frequency of TBI and to measure the association between different types of AIs and the risk of TBI among a sample of patients with facial fractures. We hypothesised that TBIs are more frequent in patients with AIs in the head and neck region and that there are some other factors predisposing for TBI in facial fracture patients.

The hypotheses were confirmed. Facial fracture patients with associated cranial fracture had a 4.7-fold risk of TBI compared with the absence of associated cranial fracture. Associated neck injury increased the risk of TBI 2.1-fold. Moreover, the odds for TBI increased 2.5 times when the injury was caused by a high energy mechanism and 2.1 times when anticoagulant medication was used. When compared with patients with exclusively mandibular fractures, patients with exclusively midfacial fractures had 1.9 times greater odds for TBI and patients with combined mandibular and midfacial fractures had 2.9 times greater odds. Increasing age was also found to increase the odds for TBI. Facial fracture patients with a confirmed cranial fracture or neck injury should be examined with special care due to the risk of TBI. In clinical work, repeated survey should be targeted especially at high-risk patients to identify TBIs. In addition, if the patient is diagnosed with TBI and a facial fracture, other injuries, especially those of the neck region and cranial bones, must also be actively determined. The study confirms a significant association of facial-fracture-related TBIs in

Table 6
Summary of multivariate logistic regression analysis for traumatic brain injury (TBI).

	OR (95% CI)	p value
AI outside the head and neck*	1.4 (0.9 to 2.0)	0.0894
Associated cranial fracture**	10.7 (7.6 to 14.9)	<0.0001
Associated neck injury***	1.6 (0.9 to 2.6)	0.0658
Age (years)****:	1.01(1.0 to 1.02)****	0.0004
at 25 yrs old	1.4 (1.2 to 1.7)	
at 40 yrs old	1.8 (1.3 to 2.4)	
at 55 yrs old	2.1 (1.4 to 3.3)	
at 70 yrs old	2.7 (1.6 to 4.6)	
at 85 yrs old	3.3 (1.7 to 6.4)	
Energy of injury***** high	2.5 (1.8 to 3.5)	<0.0001
Type of facial fracture:		0.0015
Exclusively midfacial	1.9 (1.3 to 3.0)	
Exclusively mandibular	Reference	
Combined mandibular and midfacial	2.9 (1.5 to 5.4)	
Anticoagulant therapy	2.1 (1.4 to 3.3)	0.0003

Abbreviations: AI = associated injury, CI = confidence interval.
* including upper- and lower extremity, chest, pelvic, spine (excluding cervical spine), and abdominal injuries.
** including fractures of the skull, skull base, and the upper facial third.
*** including cervical spine, blunt vessel, and laryngeal injuries.
**** odds ratio per year.
***** Road traffic-related injuries, falls from over 3 metres, and industrial injuries were classified as high-energy traumas.

patients with AIs in the head and neck region, but it is noteworthy that roughly every tenth (10.9%) facial fracture patient without other AIs (n = 1195) also had a TBI. It is also notable that in this study, 12.9% of the patients were on anticoagulation medication at the time of the injury. This can be explained by the proportion of elderly patients in the study population.

In the present study, we observed that every fifth patient with a facial fracture suffered an imaging-verified concomitant TBI. Previous studies report significantly varying rates, with 5% to 67% of TBI among patients with facial fractures,[12-18] however, these differences in results reflect a discrepancy in the definition of TBI. Many studies lack the precise information of the definition used. In addition, as motor vehicular accidents are a major aetiology for these injuries,[19,20] differences in road traffic safety, traffic rules, and regulations partly explain the variation. If mild TBIs without a radiological finding had been included in the present study, the number of these injuries would be higher.

Grant et al reported an overall TBI rate of 67% in facial fracture patients.[21] However, only 35% of the patients had documented findings on MRI. The higher occurrence of TBI compared with our study might be due to the difference in inclusion criteria of facial fracture patients. In the current study, patients with solely upper facial fractures were excluded in order to evaluate the risk of TBI in facial fracture patients when associated cranial fractures were present. In the study by Grant et al upper facial fractures such as frontal sinus fractures were included in the facial fracture population, which might explain the higher rate of TBI.[21]

Several studies have reported that facial fractures can be used as individual clinical markers for TBI [16,22] and that the possibility of TBI should always be considered when encountering a patient with fractures of the facial skeleton.[17,23,24] We have previously observed that AIs in general and TBIs in particular are common in facial fracture patients.[9] A paper published in 2012 by Puljula et al showed that TBIs associated with craniofacial fractures are at significant risk of remaining unrecorded and that the clinical specialty (other than neurology/neurosurgery) of the examining physician plays a prominent role in this failure.[25] Thus, it is crucially important to evaluate all the facial fracture patients multi-professionally, specifically the patients with AIs in the head and neck region to enable early diagnosis and intervention needed for concomitant TBI.

Young adult males suffering high energy injuries have usually been considered as being in the greatest risk of sustaining simultaneous TBI and facial fractures.[17,26] Within the progressive aging in high-income countries, changes have been seen in the epidemiological patterns of facial fractures. Several studies have showed an increase in the rate of elderly patients and the percentage of falls has increased as the mechanism of injury leading to facial fractures.[6-8] Similar changes have been seen in the epidemiology of TBI. According to Roozenbeek et al the median age of patients experiencing TBI is increasing and instead of road traffic accidents, falls have become the leading cause of TBI.[27] In the present study we saw a significant increase in the odds of TBI with increasing age. With increased life expectancy and the elderly population being increasingly active, they have become a notable group of patients in the emergency units around the western world. With pre-existing comorbidities and multiple medication, such as anticoagulant medication, elderly people are at high risk of traumatic injuries and TBIs in particular. In parallel to other studies we discovered that a high energy mechanism of trauma increased the odds for associated TBI significantly.[14,21,26] However, it is noteworthy that in the current study nearly two thirds of the patients with associated TBI suffered other than high energy trauma. The potential reason for this relates to falls dominating as the injury mechanism in older patients.

The main limitation of the present study is its retrospective nature, and there is a risk of some of the data being inadequate. In addition, the rates of TBI may have been underestimated as a result of excluding patients who did not undergo brain imaging. These potential underestimates underline the high risk of simultaneous facial fractures and TBI even more.

In conclusion, concomitant injuries in the head and neck region are significant risk factors for TBI in patients with facial fractures. On the other hand, facial fracture patients with and without TBIs often have other injuries especially outside the head and neck region. Therefore, these patients should always be evaluated multi-professionally and a proper follow-up routine should be implemented.

Conflict of interest

We have no conflicts of interest.

Funding

No funding.

Ethics statement/confirmation of patient permission

The study protocol was approved by the Internal Review Board of the Head and Neck Centre of the Helsinki University Hospital, Helsinki, Finland (HUS/356/2017). The Helsinki Declaration guidelines were followed. Patient permission not applicable in this study.

References

[1]. Hyder AA, Wunderlich CA, Puvanachandra P, et al. The impact of traumatic brain injuries: a global perspective. *NeuroRehabilitation* 2007;**22**:341–353.

[2]. Maas AI, Menon DK, Adelson PD, et al. Traumatic brain injury: integrated approaches to improve prevention, clinical care, and research. *Lancet Neurol* 2017;**16**:987–1048.

[3]. Menon DK, Schwab K, Wright DW, et al. Position statement: definition of traumatic brain injury. *Arch Phys Med Rehabil* 2010;**91**:1637–1640.

[4]. Peeters W, Van den Brande R, Polinder S, et al. Epidemiology of traumatic brain injury in Europe. *Acta Neurochir (Wien)* 2015;**157**:1683–1696.

[5]. Capizzi A, Woo J, Verduzco-Gutierrez M. Traumatic brain injury: an overview of epidemiology, pathophysiology, and medical management. *Med Clin North Am* 2020;**104**:213–238.

[6]. Yamamoto K, Matsusue Y, Murakami K, et al. Maxillofacial fractures in older patients. *J Oral Maxillofac Surg* 2011;**69**:2204–2210.

[7]. Kloss FR, Tuli T, Hächl O, et al. The impact of ageing on craniomaxillofacial trauma - a comparative investigation. *Int J Oral Maxillofac Surg* 2007;**36**:1158–1163.

[8]. Lee K. Global trends in maxillofacial fractures. *Craniomaxillofac Trauma Reconstr* 2012;**5**:213–222.

[9]. Kokko LL, Puolakkainen T, Suominen A, et al. Are the elderly with maxillofacial injuries at increased risk of associated injuries? *J Oral Maxillofac Surg* 2022;**80**:1354–1360.

[10]. Joshi UM, Ramdurg S, Saikar S, et al. Brain injuries and facial fractures: a prospective study of incidence of head injury associated with maxillofacial trauma. *J Maxillofac Oral Surg* 2018;**17**:531–537.

[11]. Evans JA, van Wessem KJ, McDougall D, et al. Epidemiology of traumatic deaths: comprehensive population-based assessment. *World J Surg* 2010;**34**:158–163.

[12]. Carlin CB, Ruff G, Mansfeld CP, et al. Facial fractures and related injuries: a ten-year retrospective analysis. *J Craniomaxillofac Trauma* 1998;**4**:44–48.

[13]. Lim LH, Lam LK, Moore MH, et al. Associated injuries in facial fractures: review of 839 patients. *Br J Plast Surg* 1993;**46**:635–638.

[14]. Pappachan B, Alexander M. Correlating facial fractures and cranial injuries. *J Oral Maxillofac Surg* 2006;**64**:1023–1029.

[15]. Arslan ED, Solakoglu AG, Komut E, et al. Assessment of maxillofacial trauma in emergency department. *World J Emerg Surg* 2014;**9**:13.

[16]. McCarty JC, Kiwanuka E, Gadkaree S, et al. Traumatic brain injury in trauma patients with isolated facial fractures. *J Craniofac Surg* 2020;**31**:1182–1185.

[17]. Rajandram RK, Syed Omar SN, Rashdi MF, et al. Maxillofacial injuries and traumatic brain injury - a pilot study. *Dental Traumatol* 2014;**30**:128–132.

[18]. Alvi A, Doherty T, Lewen G. Facial fractures and concomitant injuries in trauma patients. *Laryngoscope* 2003;**113**:102–106.

[19]. Scheyerer MJ, Döring R, Fuchs N, et al. Maxillofacial injuries in severely injured patients. *J Trauma Manag Outcomes* 2015;**9**:4.

[20]. Zhou HH, Liu Q, Yang RT, et al. Traumatic head injuries in patients with maxillofacial fractures: a retrospective case-control study. *Dent Traumatol* 2015;**31**:209–214.

[21]. Grant AL, Ranger A, Young GB, et al. Incidence of major and minor brain injuries in facial fractures. *J Craniofac Surg* 2012;**23**:1324–1328.

[22]. Mulligan RP, Mahabir RC. The prevalence of cervical spine injury, head injury, or both with isolated and multiple craniomaxillofacial fractures. *Plast Reconstr Surg* 2010;**126**:1647–1651.

[23]. Patil SG, Patil BS, Joshi U, et al. The facial skeleton: armor to the brain? *Indian J Dent* 2016;**7**:116–120.

[24]. Keenan HT, Brundage SI, Thompson DC, et al. Does the face protect the brain? A case-control study of traumatic brain injury and facial fractures. *Arch Surg* 1999;**134**:14–17.

[25]. Puljula J, Cygnel H, Mäkinen E, et al. Mild traumatic brain injury diagnosis frequently remains unrecorded in subjects with craniofacial fractures. *Injury* 2012;**43**:2100–2104.

[26]. Fernandes TB, Mandrekar PN, Visen A, et al. Pattern of associated brain injury in maxillofacial trauma: a retrospective study from a high-volume centre. *Br J Oral Maxillofac Surg* 2022;**60**:1373–1378.

[27]. Roozenbeek B, Maas AI, Menon DK. Changing patterns in the epidemiology of traumatic brain injury. *Nat Rev Neurol* 2013;**9**:231–236.