Original Article

Facial Fractures: Independent Prediction of Neurosurgical Intervention

Abstract

Context: Over half of patients with facial fractures have associated traumatic brain injury (TBI). Based on force dynamic cadaveric studies, Lefort type 2 and 3 fractures are associated with severe injury. Correlation to neurosurgical intervention is not well characterized. **Aims:** This study characterizes fracture pattern types in patients requiring neurosurgical intervention and assesses whether this is different from those not requiring intervention. Settings and Design: Retrospective data were collected from the trauma registry from 2010 to 2019. Subjects and Methods: Patients over 18, with confirmed facial fracture, reported TBI, available neuroimaging, and hospital admission were included. Statistical Analysis Used: Retrospective Contingency Analysis with Fraction of Total Comparison was used with Chi-square analysis for demographic and injury characteristic data. **Results:** One thousand and one patients required no neurosurgical intervention and 171 required intervention. The intervention group had a significantly greater number of patients with Glasgow Coma Scale (GCS) <8 compared to the nonintervention group. Subset analysis revealed a twofold increase in Lefort type 2 fractures and notable increase in Lefort type 3 and panfacial fractures in the intervention group. Patients requiring craniectomy, craniotomy, or burr holes were much more likely to have Lefort type 2 or 3 fractures compared to those only requiring external ventricular drains or intracranial pressure monitoring. Subset analysis accounting for GCS supported these results. **Conclusions:** Lefort type 2 and type 3 fractures are significantly associated with requiring neurosurgical intervention. An improved algorithm for managing these patients has been proposed in the discussion. Ongoing work will focus on validating and refining the algorithm to improve patient care.

Keywords: *Lefort type 2 and 3 fractures, neurosurgical intervention, traumatic brain injury*

Brandon Lucke-Wold[1], Kevin Pierre[2], Sina Aghili-Mehrizi[1], Gregory Joseph Anatol Murad[2]

[1]Department of Neurosurgery, University of Florida, [2]College of Medicine, University of Florida, Gainesville, FL, USA

Introduction

Roughly one of seven trauma patients admitted to the emergency room had maxillofacial fractures.[1,2] Studies have suggested an association between maxillofacial fractures and TBI.[2-20] Depending on the severity, TBI may be difficult to detect using current technology, potentially delaying treatment and worsening prognosis for patients.[4]

A recent study suggested an association between Le Fort type fractures and more severe TBI.[4,21] This is likely due to diffuse axonal injury, epidural, and subdural hematomas secondary to the high-velocity facial trauma required to produce these fractures.[4,22] Despite these findings, little is known about how fracture types predict TBI severity and which patients eventually require neurosurgical intervention. Thus, the present study is designed to develop an improved algorithm for the management of TBI in the context of known facial fractures with a hypothesis that patients with mid-face fractures are at increased risk for severe TBI warranting more aggressive neurosurgical intervention. Furthermore, we grouped by Glasgow Coma Scale (GCS) to look at trends warranting improved management strategies.

Subjects and Methods

The study was submitted for Institutional Board Review at the University of Florida and abided by the highest international ethical research standards. Retrospective analysis of patients from 2010 to 2019 was obtained through our trauma registry. Inclusion criteria were adults over 18, confirmed facial fracture with available neuroimaging, reported traumatic brain injury (TBI), and admission to ICU or floor bed. Exclusion criteria were patients <18 years old, patients with no

How to cite this article: Lucke-Wold B, Pierre K, Aghili-Mehrizi S, Murad GJ. Facial fractures: Independent prediction of neurosurgical intervention. Asian J Neurosurg 2021;16:792-6.

Submitted: 21-Jun-2021 **Revised:** 19-Jul-2021
Accepted: 01-Sep-2021 **Published:** 18-Dec-2021

Address for correspondence:
Dr. Brandon Lucke-Wold, Department of Neurosurgery, University of Florida, 1505 SW Archer Rd, Gainesville, FL 32608, USA. E-mail: brandon.lucke-wold@neurosurgery.ufl.edu

Access this article online

Website: www.asianjns.org

DOI: 10.4103/ajns.AJNS_251_21

Quick Response Code:

neuroimaging, and patients that were deceased prior to initiation of neurosurgical intervention.

In addition to basic demographic data, data collected included presenting GCS score, mechanism of injury, facial fracture type, TBI type, and type of neurosurgical intervention. Age was grouped into seven categories: 1 (18–24 years old), 2 (25–34 years old), 3 (35–44 years old), 4 (45–54 years old), 5 (55–64 years old), 6 (65–74 years old), and 7 (>75 years old). The race was grouped into five categories: 1 (Caucasian), 2 (Black), 3 (Asian), 4 (Hispanic), and 5 (Other). Sex was classified as male or female. GCS score was arranged: mild (14–15), moderate (9–13), or severe (8 or less). Mechanism of injury was grouped into seven categories: 1 (assault), 2 (all-terrain vehicle or dirtbike accident), 3 (gunshot wound or knife injury), 4 (bicycle or moped accident), 5 (motorcycle collision or motor vehicle collision), 6 (fall), and 7 (other). Type of TBI: 1 (contusion), 2 (diffuse axonal injury), 3 (epidural hematoma), 4 (subdural hematoma), 5 (traumatic subarachnoid hemorrhage), 6 (intracranial hemorrhage or intraventricular hemorrhage), and 7 (penetrating injury). Additional radiographic findings divided into four categories: 1 (edema), 2 (herniation), 3 (pneumocephalus), and 4 (cerebral/cerebellar laceration).

Patients were divided into those with facial fracture and TBI without neurosurgical intervention and those with facial fracture and TBI with neurosurgical intervention. Graphpad Prism 8.0 Software was used for analysis. Retrospective Contingency Analysis with Fraction of Total Comparison was used with Chi-square analysis for demographic and injury characteristic data. $P < 0.05$ was considered statistically significant.

Results

Based on the above inclusion/exclusion criteria, 1985 patients were pooled from the overall trauma registry. On further review, 316 were too young, 403 had no TBI, and 94 had no facial fracture. One thousand one hundred and seventy-two patients therefore met the criteria for inclusion into the study. One thousand and one had facial fracture and TBI with no neurosurgical intervention, 171 had facial fracture and TBI with neurosurgical intervention. Table 1 shows baseline demographic data. No significant difference was seen between groups for age ($\chi^2 = 8.08$, $P = 0.23$), race ($\chi^2 = 0.6$, $P = 0.96$), or gender ($\chi^2 = 1.33$, $P = 0.25$).

Injury characteristics are compared in Table 2. A significant difference was seen between groups for presenting GCS ($\chi^2 = 67.71$, $P < 0.001$). Of note, in the nonintervention group, 64% had mild GCS score (14–15) compared to 10% of the intervention group. Conversely, 74% of the intervention group had severe GCS score (3–8) compared to 22% of the nonintervention group. No significant difference was seen between groups for mechanism of injury ($\chi^2 = 7.58$, $P = 0.27$), type of TBI ($\chi^2 = 3.09$, $P = 0.8$), or additional radiographic findings ($\chi^2 = 1.71$, $P = 0.63$).

Fracture type patterns were similar between the nonintervention and intervention group ($\chi^2 = 4.518$, $P = 0.92$) as seen in Figure 1. Subset analysis did however reveal a twofold increase in Lefort type 2 and panfacial fractures in the intervention group compared to nonintervention group. In the intervention group, 136/171 required an ICP monitor or external ventricular drain (EVD) only, 12/171 required a craniotomy, craniectomy, or burr holes only, 23/171 required a craniotomy, craniectomy, or burr holes with EVD or ICP monitor [Figure 2]. A significant difference was seen in type of intervention depending on presenting facial fracture pattern ($\chi^2 = 20.02$, $P = 0.03$). Of note, 24% of the craniotomy, craniectomy, and burr hole group had Lefort type 2 fracture compared to only 9% in the ICP monitor only group. About 15% of the craniotomy, craniectomy, and burr hole group had Lefort

Table 1: Demographics

	Nonintervention (*n*=1001), *n* (%)	Intervention (n=171), *n* (%)	*P*
Age (years)			
18-24	176 (17)	36 (21)	>0.05
25-34	165 (17)	39 (23)	
35-44	151 (15)	21 (12)	
45-54	169 (17)	33 (19)	
55-64	128 (13)	28 (16)	
65-74	94 (9)	10 (6)	
75+	118 (12)	4 (3)	
Race			
Caucasian	826 (83)	135 (79)	>0.05
Black	118 (11)	24 (14)	
Asian	5 (1)	1 (1)	
Hispanic	34 (3)	7 (4)	
Other	18 (2)	4 (2)	
Gender			
Male	723 (72)	136 (79)	>0.05
Female	278 (28)	35 (21)	

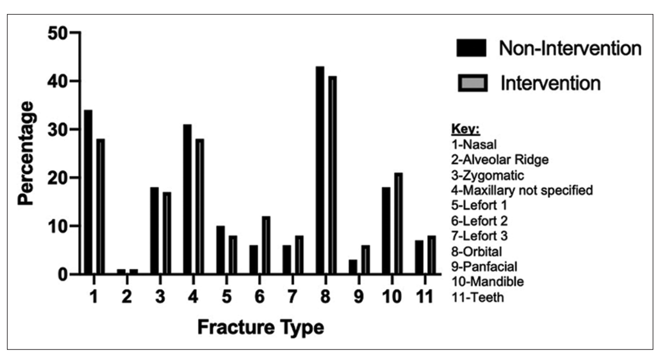

Figure 1: Patients in intervention vs. nonintervention group by type of facial fracture. No overall significant difference in aggregate fracture pattern between groups. However, there were more Lefort type 2, Lefort type III, and panfacial fractures in the intervention group

Table 2: Injury characteristics

	Nonintervention (*n*=1001), *n* (%)	Intervention (*n*=171), *n* (%)	*P*
GCS			
1. Mild (14-15)	636 (64)	17 (10)	<0.001
2. Moderate (9-13)	140 (14)	27 (16)	
3. Severe (3-8)	226 (22)	127 (74)	
Mechanism of injury			
1. Assault	160 (16)	16 (9)	>0.05
2. ATV/dirtbike	44 (4)	11 (6)	
3. GSW/knife	46 (5)	9 (5)	
4. Bicycle/moped	74 (7)	18 (11)	
5. MCC/MVC	381 (38)	77 (45)	
6. Fall	212 (22)	19 (12)	
7. Other	84 (8)	21 (12)	
Types of TBI			
1. Contusion	61 (6)	21 (12)	>0.05
2. DAI	31 (3)	23 (13)	
3. EDH	49 (5)	22 (13)	
4. SDH	201 (20)	63 (37)	
5. tSAH	295 (29)	79 (46)	
6. ICH/IVH	66 (7)	27 (16)	
7. Penetrating injury	11 (1)	1 (1)	
Additional radiographic findings			
1. Edema	25 (2)	20 (12)	>0.05
2. Herniation	32 (3)	25 (15)	
3. Pneumocephalus	34 (3)	10 (6)	
4. Cerebral/cerebellar laceration	5 (1)	4 (2)	

GCS - Glasgow Coma Scale; TBI - Traumatic brain injury; ATV - All-terrain vehicle; GSW - Gunshot wound; MCC - Motorcycle collision; MVC - Motor vehicle collision; DAI - Diffuse axonal injury; EDH - Epidural hematoma; SDH - Subdural hematoma; tSAH - Traumatic subarachnoid hemorrhage; ICH - Intracranial hemorrhage; IVH - Intraventricular hemorrhage

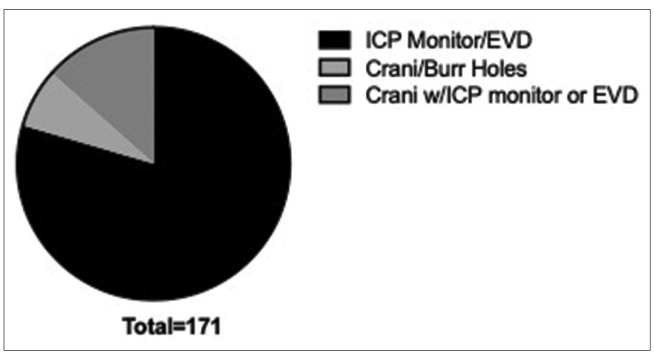

Figure 2: Type of neurosurgical intervention for trauma patients with facial fractures. ICP – Intracranial pressure; EVD – External ventricular drain; Crani – decompressive craniectomy, craniotomy, or burr holes

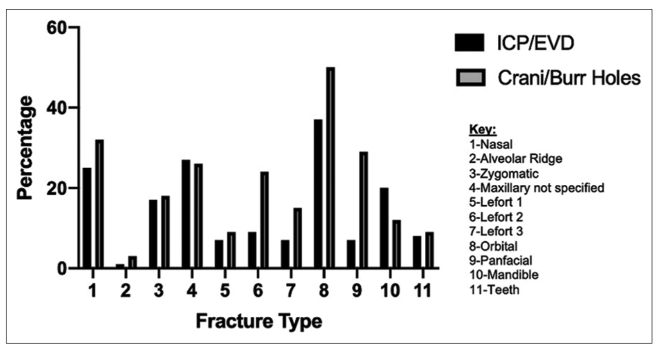

Figure 3: Lefort type 2, and panfacial fractures, and 3 fractures were common in the craniotomy, craniectomy, burr hole group compared to intracranial pressure monitor only group. These results were statistically significant

type 3 fracture compared to only 7% in the ICP monitor only group. Only 29% of the craniotomy/burr hole group had panfacial fractures compared to 7% of the ICP monitor only group [Figure 3].

Further subset analysis was done to compare Lefort type 2 and 3 fractures based on GCS scores for each group. A significant difference was seen (χ^2 = 8.44, P = 0.01). Of patients with GCS 14–15, 7% of the nonintervention group had Lefort type 2 and 3 fractures compared to 6% of the intervention group. A notable difference however was seen for patients presenting with GCS 9–13 with only 11% of patients in the nonintervention group having Lefort type 2 and 3 fractures compared to 40% in the intervention group. In addition, for patients with GCS, less or equal to 8 17% of the nonintervention group had Lefort type 2 and 3 fractures compared to 19% of the intervention group [Figure 4].

Discussion

Traumatic injury is a leading cause of death and disability worldwide.[23] A significant number of trauma victims present with maxillofacial fractures, with roughly half of these patients presenting with TBI.[1,2,24] There is a growing body of literature suggesting that maxillofacial fractures serve as predictors for the presence and severity of TBI.[4,7,9,10,13,17,21] This study aimed to determine whether certain types of maxillofacial fractures can predict the need for neurosurgical interventions in an effort to produce an algorithm for the management of TBI patients presenting with known facial fractures.

A retrospective analysis of patients admitted to a major academic hospital trauma center between 2010 and 2019 with known facial fractures and concurrent TBI was performed. Most patients were victims of motor vehicle collisions, motorcycle accidents, and falls. Most suffered orbital, nasal, and maxillary fractures in a distribution similar to the study done by Menon *et al*. with patients sharing similar demographics.[25] Patients were not more likely to require intervention based on age, race, gender, mechanism of injury, or specific radiologic findings of edema, herniation, pneumocephalus, or laceration. As anticipated, those taken for intervention had higher GCS scores. When a subset analysis was performed, however, even patients with GCS scores 9–13 were more likely to require subsequent intervention if they had Lefort type 2 and 3 fractures lending credence to the individual predictive indication of these fracture types.

Patients with Le Fort type II, type III, and panfacial fractures were more likely to undergo neurosurgical intervention. Further, those presenting with these severe fractures were more likely to receive higher levels of neurosurgical intervention involving craniotomies, craniectomy, and burr holes compared to only EVDs or ICP monitors. This is consistent with the initial hypothesis that the high-velocity impacts required to produce the more severe type II and III Le Fort type fractures[22,26] are also more likely to lead to more severe neurologic injury. These results also support previous investigations that showed associations between midface fractures and more severe TBI.[21]

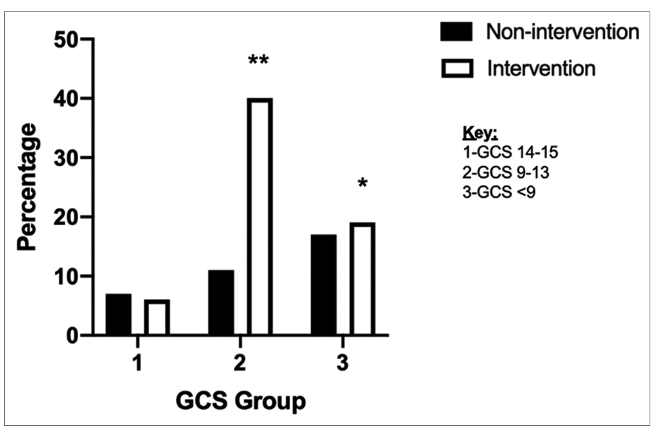

Figure 4: A significant difference was seen between the nonintervention and intervention groups in regard to Lefort type 2 and 3 fractures when subanalysis was done based on Glasgow Coma Scale. 1 = GCS 14-15, 2 = GCS 9-13, 3 = GCS < 9. **P < 0.01, *P < 0.05

Improved algorithms to identify and triage patients with facial fractures that are more likely to require neurosurgical interventions are being designed in collaboration with the hospital trauma, plastic, and oral and maxillofacial surgeon colleagues. Figure 5 shows an improved decision tree algorithm for managing patients with severe TBI and to have greater clinical suspicion for decline in moderate TBI patients with Lefort type 2 and 3 facial fractures. This algorithm is influenced by this study's findings and Czerwinski's *et al.*'s proposition for mandatory early computed tomography of the head to rule out TBI in patients presenting with facial fractures. This argument was also supported by Shibuya and *et al.*'s study which showed that 11% of patients who underwent facial fracture repair had worsened GCS score following intervention due to underlying TBI.[27,28] Early surgical interventions improve outcomes.[29] The hope is that through initiation of the improved algorithm, early imaging can be obtained, improved interactions between specialties can enhance patient care and ultimately allow providers to quickly intervene when indicated.

This study's retrospective nature serves as a limitation. The study was also limited by the trauma registry. For example, it was not possible to separately consider the use of EVDs versus other intracranial pressure monitoring devices because providers sometimes did not use specific International Classification of Diseases (ICD) coding. ICD coding also sometimes did not specify fracture types, only indicating the presence of a facial fracture. These injuries were successfully categorized by chart review. However, it is possible that some facial fractures for patients within this group were not recorded.

We hope that the data and results from this initial study will serve as a catalyst for prospective investigations. Subsequent studies may prospectively implement the algorithm in patients with facial fractures and TBI to directly evaluate its effectiveness. This will allow direct evaluation of effectiveness. Future studies can also implement the finite element head models reviewed and

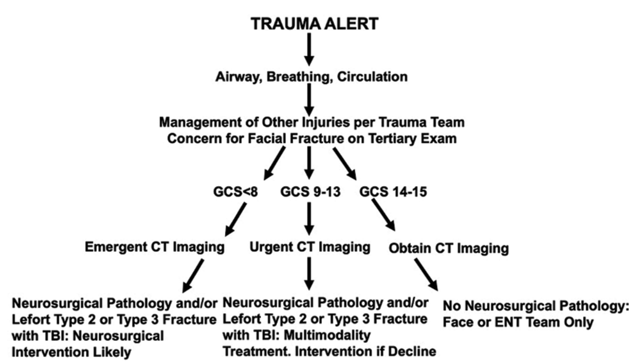

Figure 5: Improved algorithm for managing patients with suspected TBI and facial fractures. Patients with Lefort type 2 or 3 fractures are at greater likelihood for requiring neurosurgical intervention and should be grouped accordingly

developed by Tse *et al*. to further determine fracture patterns more likely to be associated with severe TBI.[30,31]

Acknowledgment

We would like to thank Tabetha Harris for her help in obtaining and interpreting the data from the trauma registry.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Hwang K, You SH. Analysis of facial bone fractures: An 11-year study of 2,094 patients. Indian J Plast Surg 2010;43:42-8.
2. Martin RC 2nd, Spain DA, Richardson JD. Do facial fractures protect the brain or are they a marker for severe head injury? Am Surg 2002;68:477-81.
3. Pham TT, Lester E, Grigorian A, Roditi RE, Nahmias JT. National analysis of risk factors for nasal fractures and associated injuries in trauma. Craniomaxillofac Trauma Reconstr 2019;12:221-7.
4. McCarty JC, Kiwanuka E, Gadkaree S, Siu JM, Caterson EJ. Traumatic brain injury in trauma patients with isolated facial fractures. J Craniofac Surg 2020;31:1182-5.
5. Keenan HT, Brundage SI, Thompson DC, Maier RV, Rivara FP. Does the face protect the brain? A case-control study of traumatic brain injury and facial fractures. Arch Surg 1999;134:14-7.
6. Rajandram RK, Syed Omar SN, Rashdi MF, Abdul Jabar MN. Maxillofacial injuries and traumatic brain injury – A pilot study. Dent Traumatol 2014;30:128-32.
7. You N, Choi MS, Roh TH, Jeong D, Kim SH. Severe facial fracture is related to severe traumatic brain injury. World Neurosurg 2018;111:e47-52.
8. Joshi UM, Ramdurg S, Saikar S, Patil S, Shah K. Brain injuries and facial fractures: A prospective study of incidence of head injury associated with maxillofacial trauma. J Maxillofac Oral Surg 2018;17:531-7.
9. Zandi M, Seyed Hoseini SR. The relationship between head injury and facial trauma: A case-control study. Oral Maxillofac Surg 2013;17:201-7.
10. Kraus JF, Rice TM, Peek-Asa C, McArthur DL. Facial trauma and the risk of intracranial injury in motorcycle riders. Ann Emerg Med 2003;41:18-26.
11. Carlin CB, Ruff G, Mansfeld CP, Clinton MS. Facial fractures and related injuries: A ten-year retrospective analysis. J Craniomaxillofac Trauma 1998;4:44-8.
12. Salentijn EG, Peerdeman SM, Boffano P, van den Bergh B, Forouzanfar T. A ten-year analysis of the traumatic maxillofacial and brain injury patient in Amsterdam: Incidence and aetiology. J Craniomaxillofac Surg 2014;42:705-10.
13. Luce EA, Tubb TD, Moore AM. Review of 1,000 major facial fractures and associated injuries. Plast Reconstr Surg 1979;63:26-30.
14. Lee KF, Wagner LK, Lee YE, Suh JH, Lee SR. The impact-absorbing effects of facial fractures in closed-head injuries. An analysis of 210 patients. J Neurosurg 1987;66:542-7.
15. Lim LH, Lam LK, Moore MH, Trott JA, David DJ. Associated injuries in facial fractures: Review of 839 patients. Br J Plast Surg 1993;46:635-8.
16. Pappachan B, Alexander M. Correlating facial fractures and cranial injuries. J Oral Maxillofac Surg 2006;64:1023-9.
17. Lee HJ, Kim YJ, Seo DW, Sohn CH, Ryoo SM, Ahn S, *et al*. Incidence of intracranial injury in orbital wall fracture patients not classified as traumatic brain injury. Injury 2018;49:963-8.
18. Alvi A, Doherty T, Lewen G. Facial fractures and concomitant injuries in trauma patients. Laryngoscope 2003;113:102-6.
19. Suri YV, Qasba KK, Mahajan TR. Militancy trauma: Maxillofacial injury, anaesthesia and critical care. Med J Armed Forces India 1996;52:23-6.
20. Davidoff G, Jakubowski M, Thomas D, Alpert M. The spectrum of closed-head injuries in facial trauma victims: Incidence and impact. Ann Emerg Med 1988;17:6-9.
21. Elbaih AH, El-Sayed DA, Abou-Zeid AE, Elhadary GK. Patterns of brain injuries associated with maxillofacial fractures and its fate in emergency Egyptian polytrauma patients. Chin J Traumatol 2018;21:287-92.
22. Roumeliotis G, Ahluwalia R, Jenkyn T, Yazdani A. The Le Fort system revisited: Trauma velocity predicts the path of Le Fort I fractures through the lateral buttress. Plast Surg (Oakv) 2015;23:40-2.
23. Søreide K. Epidemiology of major trauma. Br J Surg 2009;96:697-8.
24. Scheyerer MJ, Döring R, Fuchs N, Metzler P, Sprengel K, Werner CM, *et al*. Maxillofacial injuries in severely injured patients. J Trauma Manag Outcomes 2015;9:4-4.
25. Menon S, Sham ME, Kumar V, Archana S, Nath P, Shivakotee S, *et al.* Maxillofacial fracture patterns in road traffic accidents. Ann Maxillofac Surg 2019;9:345-8.
26. Phillips BJ, Turco LM. Le fort fractures: A collective review. Bull Emerg Trauma 2017;5:221-30.
27. Czerwinski M, Parker WL, Williams HB. Algorithm for head computed tomography imaging in patients with mandible fractures. J Oral Maxillofac Surg 2008;66:2093-7.
28. Shibuya TY, Karam AM, Doerr T, Stachler RJ, Zormeier M, Mathog RH, *et al.* Facial fracture repair in the traumatic brain injury patient. J Oral Maxillofac Surg 2007;65:1693-9.
29. Giuliani G, Anile C, Massarelli M, Maira G. Management of complex craniofacial traumas. Rev Stomatol Chir Maxillofac 1997;98 Suppl 1:100-2.
30. Tse KM, Lim S, Tan VB, Lee H. A review of head injury and finite element head models. Am J Eng Technol Soc 2014;1:28-52.
31. Yang B, Tse KM, Chen N, Tan LB, Zheng QQ, Yang HM, *et al*. Development of a finite element head model for the study of impact head injury. Biomed Res Int 2014;2014:408278.