



REVIEW ARTICLE

Cervical Spine Injuries and Maxillofacial Trauma: A Systematic Review



Feras AlMofreh, DDS^{a,*}, Sami AlOtaibi^b, Mohamed Jaber^c,
Khaled Bishawi, DDS^d, Ahmed AlShanably, DDS^e, Faris AlMutairi^f

^a Intern, Specialist Dental Hospital, Dammam Medical Complex, Saudi Arabia

^b Department of Oral and Maxillofacial Surgery, King Saud University, Saudi Arabia

^c Department Head, Surgical Sciences, Ajman University, United Arab Emirates

^d General Practitioner, Chicago Illinois, USA

^e General Dentist, College of Dentistry, Ajman University, United Arab Emirates

^f Department of Oral and Maxillofacial Surgery and Diagnostic Sciences, College of Dentistry, Qassim University, Saudi Arabia

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Abstract *Objectives:* Identify specific maxillofacial trauma patterns associated with cervical spine injuries.

Methods: The protocol was developed according to (PRISMA-P) and was admitted to PROSPERO under accreditation code #CRD42020177816. Furthermore, the reporting of the present SR was conducted based on the PRISMA checklist.

Results: Of the 1,407,750 patients recorded, a total of 115,997 patients (12.13%) had MFT with an associated CSI with a gender proportion (M:F) of 3.63:1 respectively. Motor vehicle accident was the most common cause of the combined Maxillofacial Trauma (MFT) and CSI. The most common CSI location was at the C2, followed by the C5 cervical spines. The most common location of a maxillofacial fracture resulting in a CSI was the mandible.

Conclusion: The incidence of the association of CSIs with MFT has been low (12.13%). Nevertheless, in cases of an isolated mandibular trauma due to a severe blow presenting with a low Glasgow Coma Scale, maxillofacial surgeons should be at a high alert of an associated CSI.

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* Corresponding author.

E-mail address: Ferasalqahtani11@gmail.com (F. AlMofreh, DDS).

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1. Introduction

Maxillofacial trauma (MFT) is considered to be one of the major health problems worldwide because of the sensitivity of the involved region (Schafteenaar et al., 2009) and the psychological consequences, which may affect the quality of life of patients with facial trauma (Wulkan et al., 2005).

Facial trauma has been reported to be associated with other severe injuries and tends to distract our attention from carefully assessing injuries that can result in a devastating sequela (Hohlrieder et al., 2004).

One of the known injuries that have been reported in the literature to be associated with facial trauma is the cervical spine injury (CSI). It has been shown that CSI associated with facial trauma may result from forces transmitted directly or indirectly to cervical structures in both bony and soft tissues (Ardekian et al., 1997). The presence of CSI in patients with facial trauma may influence the management of these injuries in terms of timing and surgical interventions. The prevalence of CSI in patients with facial trauma varies in literature as differences transpire in the mechanism of injuries and anatomical location of facial trauma (Beirne et al., 1995).

Facial fractures lean to distract our attention from more severe injuries (Hohlrieder et al., 2004); thus, the trauma protocols such as the ATLS® manual highlights the significance of the correlation between MFT and CSI and the ramification which could arise if the diagnosis is missed or its occurrence or absence is overlooked (American College of Surgeons, 2008).

Thus, this article aimed to determine the elements correlated to CSI in patients with MFT

2. Materials and methods

2.1. Reporting

The protocol was developed according to (PRISMA-P) and was admitted to PROSPERO under the accreditation code

#CRD42020177816. Furthermore, the reporting of the present SR was conducted based on the PRISMA checklist.

2.2. Information sources and search strategy

PubMed, EMBASE, and Cochrane databases; Scopus; and Google Scholar from 1985 to 2019 were reviewed to determine relevant studies.

We reviewed all publications that were in English language focusing on the association of CSI among MFT patients. Articles were searched for the association, epidemiology, correlation, and prevalence of CSI and MFT, collateral injuries, and a combination of these terms in the title. Data collected from each study include age, gender, type of MFF, causes of MFF, CSI, and complications associated with facial fractures. Studies that are non-English or that described non-facial fractures were excluded. The Medical Subject Heading terms selected for this search included “*facial injuries*,” “*cervical Spine Injuries*,” “*maxillofacial injuries*,” “*etiology*,” “*trauma*,” “*MVA*,” and “*C2–C5*,” To stipulate the search, the term NOT was used to eliminate the following words: “*animals*,” “*burns*,” “*facial nerve*,” and “*eye*,” due to the high amount of articles are associated with mentioned words. The titles of the respective identified articles were then evaluated for potential associations between MFTs and CSIs, motor vehicle accident (MVA), violence or assaults, sport-related injuries, falls and industrial causes, concomitant MFF, and CSI, and a combination of these terms. Consequently, we used the PECO framework, which stands for **P** (Patient Population), **I** (Intervention or Exposure—in case of observational studies), **C** (Comparison), and **O** (Outcomes). In this systematic review, the PECO approach involved Population (children and adults with MFT and an associated CSI), Exposure (MFT with CSI), Comparison (the percentage of MFF associated with CSI and type and location of injuries), and Outcome (the prevalence of the association of MFF and CSI).

2.3. Eligibility criteria

The following eligibility criteria were applied to obtain articles that were correlated to the current review: Studies should be

available as full-text articles and not in the form of an abstract. Moreover, they should apply a retrospective or prospective design that focuses on all age groups (both children and adults). Moreover, studies in which fractures were diagnosed as a result of patients' complaints and clinical examinations and were then confirmed radiographically and clinically were included. For each of the included articles, a data collection form was used to collect data, including country, study interval, age group, the ratio of gender proportion, causes of MFF and CSI, and site of injuries. Studies with the following characteristics were excluded: studies providing only epidemiological data on specific groups or specific conditions (such as children, old people, and military exercises). Meta-analysis was not performed because of high heterogeneity between study variables

2.4. Quality of the studies

We used the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist⁸ to assess the risk of bias in all established and collected full-text articles included in this study as follows: (a) had clearly defined the source of participant selection, (b) had clearly defined eligibility criteria, (c) explained how exposure was measured, (d) explained how outcomes were measured, (e) provided appropriate follow-up information, (f) defined sample sizes, and (g) had clearly defined aims and objectives. The quality of the included studies was assessed independently by two authors (FQ and AD). Thirteen checklist criteria were selected, and the collected studies were classified into 3 categories: studies presenting 10 out of 13 criteria were selected as having a low risk of bias, those presenting 6–9 criteria were considered as having a moderate risk of bias, and those presenting only 5 criteria were selected as having a high risk of bias (Table 1). The value of the weighted kappa statistic between author agreements was 87%. After confirming the quality of each study, two authors (FQ and AD) independently extracted the data to the pre-specified data extraction sheet in Microsoft Excel. Variables extracted from each eligible study include the name of the first author, year of publication, length of the study, location of the study, study design, median follow-up time, source of data, sample size, mean age, causes of MFF, and site

3. Results

3.1. Study selection

The search strategy resulted in 25 studies, and after removing duplicates, 23 studies were included for full-text reading. Subsequently, 4 studies were excluded because they failed to fulfill the eligibility criteria, and hence, 19 studies were included for analysis in this systematic review (Fig. 1).

3.2. Study characteristics

A total of 19 articles published between 1985 and 2019 that satisfied our inclusion criteria were included in the review. All 19 studies selected were classified as having a low risk of bias (Table 1).

Of the 1,407,750 patients recorded, a total of 115,997 patients (12.13%) sustained an MFF with an associated CSI with a gender proportion (M:F) of 3.63:1 respectively. with an age range of 0–103 years (Table 1). MVA was the most common cause of the combined MFT and CSI. The most common CSI location was at the C2, followed by the C5 cervical spines. The most common location of an MFF resulting in a CSI was at the mandible (Table 2).

4. Discussion

Facial trauma involves trauma to the head, face, and jawbones (Kheirallah and Almeshaly, 2016). Facial trauma is highly prevalent worldwide and is a frequent cause of admission into the emergency wards since the face is the most unprotected part of the body (Jaber et al., 2021). By the age of 40, trauma is the most common cause of death (Obuekwe et al., 2005), and facial injuries are one of the most common traumatic injuries reported to emergency departments (Jose et al., 2016). The etiology of facial trauma is dependent on the culture and the socio-economic status of each country (Arslan et al., 2014).

It was found in this study that MVA is the leading cause of the combined MFT and CSIs. The findings in this study are similar to those of other studies that reported that MVA is the major causative factor of the combined MFT and CSI (Färkkilä et al., 2019; Mukherjee et al., 2015). This may be because the force of impact in an MVA is strong, in which the force from the facial region is distributed into the cervical spine area (Ardekian et al., 1997). Another fact is the possibility of the head being overflexed or overextended during the impact resulting in a CSI (American College of Surgeons 2008b).

The mandible was found to be the most frequent location of the combined MFT and CSI; this may be because it is an isolated and the least protected bone in the facial skeleton (Oji, 1999), and it is considered to be the largest and the most prominent bone (Nwoku, 2004). Nevertheless, the U shape pattern of the mandible has also been reported to increase the risk of mandibular fractures (Infante Cossio et al., 1994). The mandible was also found to be the most common location of the combined MFT and CSI in several other studies (Chen, 2008; Soleimani et al., 2015). However, Sajjad et al (Rahman and Chandrasala, 2014) reported that the midface was the most common location of fractures that result in CSI following an MFT.

The mandible and the midface were highly involved as the major areas of facial injuries that result in cervical spine involvement; this can be explained by the possible association of the upper cervical compartments with the mandible and the lower cervical compartments with the midface (Lalani and Bonanthaya, 1997).

Males outnumbered females in our review with a ratio of 3.74:1. This finding is in line with those of other studies that reported male predominance of injury with 2.7:1 (Obuekwe and Etetafia, 2004), 6:1 (Hussain et al., 2003), and 1.74:1 (Li et al., 2015). The high male predominance is due to high outdoor activities, lack of awareness, higher sports involvement, and higher weapon availability among males (Boffano et al., 2014).

Table 1 Quality assessment of the studies using STROBE criteria (Y = presence of criteria) STROBE criteria checklist was used to identify the articles were involved within the current study **Thirteen** characteristics elected Articles with **Ten out of Thirteen** characteristics were selected as **low-risk** bias, Approximately **Six to Nine** criteria were considered as **moderate-risk** bias, Articles which had **only Five** were selected as **high-risk** bias.

Author/Year	Inclusion & exclusion criteria	Study design	Data source	Study size	Statistical method	Summary of results	Follow-up	Outcome	Treatment	Limitation	Objective	Risk of bias
Haug,1991	Y	Y	Y	Y		Y		Y	Y	Y	x	11
Lalani and Bonanthaya, 1997	Y	Y	Y	Y		Y		Y		Y	x	10
Hackl, 2001	Y	Y	Y	Y		Y		Y		Y	x	10
Mukherjee, 2015	Y	Y	Y	Y		Y		Y		Y	x	10
Kumar, 2017	Y	Y	Y	Y		Y		Y		Y	x	10
Bayles, 1997	Y	Y	Y	Y		Y		Y		Y	x	10
Beirne, 1995	Y	Y	Y	Y		Y		Y		Y	x	10
Färkkilä, 2019	Y	Y	Y	Y		Y		Y		Y	x	10
Chu et al., 2016	Y	Y	Y	Y		Y		Y		Y	x	10
Kumar, 2009	Y	Y	Y	Y		Y		Y		Y	x	10
Reich et al, 2016	Y	Y	Y	Y		Y		Y		Y	x	10
Soumithran and Philip, 2007	Y	Y	Y	Y		Y		Y		Y	x	10
Mourouzis, 2018	Y	Y	Y	Y		Y		Y		Y	x	10
Jamal, 2009	Y	Y	Y	Y		Y		Y		Y	x	10
Lewis, 1985	Y	Y	Y	Y		Y		Y		Y	x	10
Mulligan, 2010	Y	Y	Y	Y		Y		Y		Y	x	10
Davidson, 1989	Y	Y	Y	Y		Y		Y		Y	x	10
Jonathan Zelken, 2014	Y	Y	Y	Y		Y		Y		Y	x	10

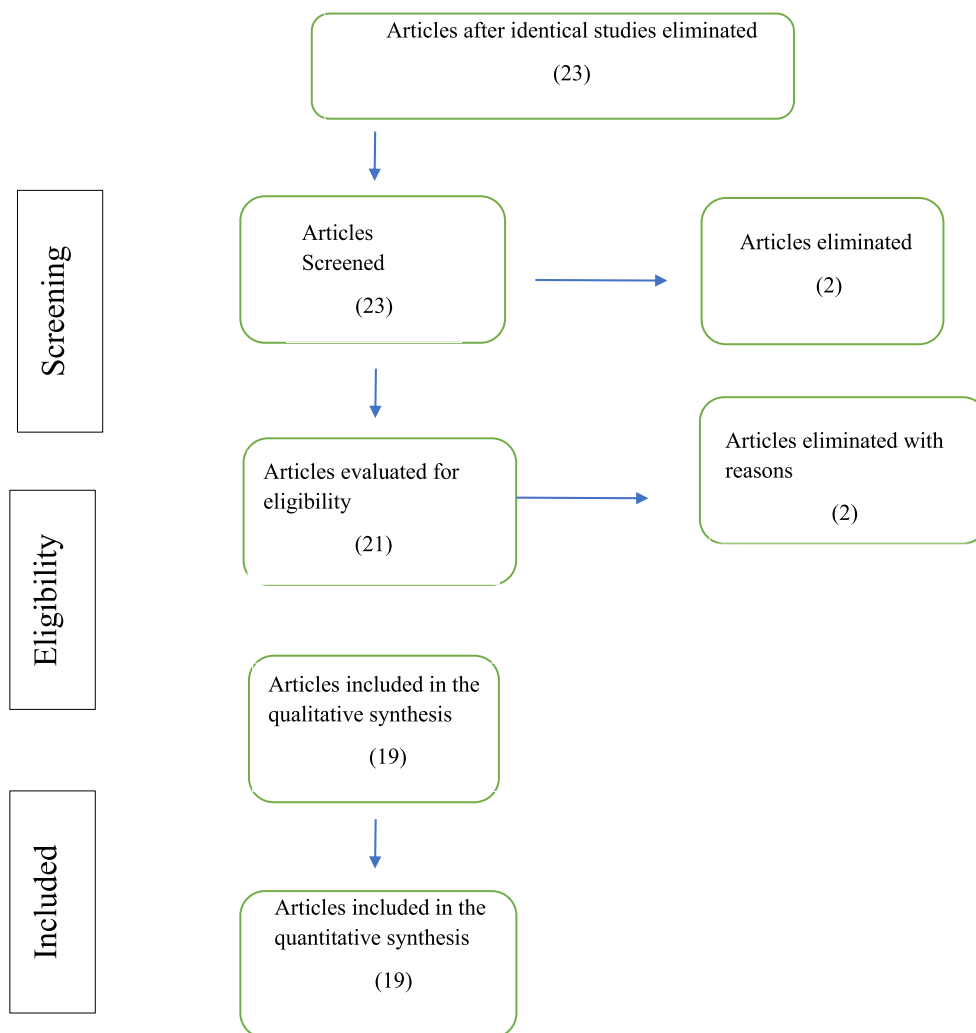


Fig. 1 Prisma chart.

The association of CSIs with MFFs recorded in this study was 12.3%, which appears to be higher than those in other studies, in which a percentage of CSI involvement ranging from 1% (Baker and Mackenzie, 1976) to 6% (Tu et al., 2010) has been recorded; the resultant outcome however, is mostly due to the larger number of patients in the current review

The most common location of CSIs in this study was at the C2 level. This finding is in line with that of other studies reporting that the C2 spine was the most commonly involved vertebrae (McMordie et al., 2020; Menger et al., 2020). This may be explained by the fact that cervical spine fractures are mainly due to improper movements such as hyper flexion, hyperextension, and rotational movements (Modi et al., 2016) of the C2 spine, which has been reported to account for 50% of the rotational movements due to the loose articular capsules (Bhimani et al., 2018).

Another explanation of this finding is the possible relation of C2 injury with patients' age as suggested by Ryan and Henderson (Ryan and Henderson, 1992), who noted that C2 injuries may increase with age, which is demonstrated in the current study where all patients with an involved C2 spine injury are adults. This is also explained

by the fact that adults have a low cranial-facial ratio of 2.5:1, whereas children have a cranial-facial ratio of 8:1 in addition to underdeveloped paranasal sinuses and unerupted teeth, making their facial skeleton more volatile and solid (Zimmermann et al., 2005).

Approximately 4%–30% of CSIs have been neglected and unreported (Bohlanman, 1979; Gerrelts et al., 1991). Computed tomography (CT) scan should always be included in MFT's ruling out of a possibility of CSI. Nevertheless, CT scans have been reported to have a 0.04% percentage of missing out on a CSI (Sanchez et al., 2005). By contrast, lateral view radiographs should be avoided because they result in false-negative imaging that can reach up to 40% (Andrew et al., 1992) and inadequately records significant anatomic structures such as the odontoid process (Ardekian et al., 1997; Beirne et al., 1995). Therefore, CT should always be the first imaging technique when a CSI is suspected along with MFT. However, signs and symptoms of high-risk patients should be known to aid in early detection of a possible association of CSI, which include patients with altered sensation, conscious patients complaining of cervicgia or discomfort, and victims with nervous system disorders (Roccia et al., 2007).

Table 2 Main Results and Outcomes of the associated CSI and MFT.

Author/year	Mean age	Cause of combined MFT and CSI	Location of MFT	Location of CSI	Type of CSI	M:F ratio	MFT with CSI (%)	Total
Haug et al., 1991	25 Years	MVA (91%)	Mandible (91%)	*	Subluxation	10.1:1	2	563
Lalani and Bonanthaya, 1997	40 Years	MVA	*	C5-C7	Fracture with a neurological defect	7:1	3	536
Hackl et al., 2001	42 Years	MVA (43.7%)	Midface	*	Sprain (whiplash injury)	2.3:1	6.7	2877
Mukherjee et al., 2015	44 Years	MVA (88%)	Midface	C1-C2 C6-C7	Subluxation and dislocation	3:2	2.2	714
Kumar, 2017	33 Years	MVA (46.15%)	Mandible	C2	*	1.49:1	100	169
Bayles et al., 1997	32 Years	Assault (68.2%)	Mandible	C1-C8	Distracting injury	5.4:1	0.6	2121
Beirne et al., 1995	*	Assault (43.9%)	Mid-Facie	C2-C4 C5-C7	Neck pain and discomfort	*	1.04	582
Färkkilä et al., 2019	40	MVA	Mandible	C2	Fracture of the cervical spine	5.25:1	7.7	23,394
Chu et al., 2017	*	Firearm (12.2%)	Mandible	*	*	**	10.8	59,028
Kumar et al., 2009	96 Years	MVA 75%	Mandible and midface	C1-C2 C6-C7			2.24	714
Reich et al., 2016	56.2 Years	MVA	Midface	C2	Dens Axis Anderson Type II	1.38:1	5.7	3956
Soumithran and Philip, 2007	*	MVA (66.6%)	Midface	*	*	*	1.07	4460
Mourouzis et al., 2018	39.81 Years	MVA (77.3%)	Mandible zygomatic process	C6-C7	Transverse and spinous processes fracture	1.75:1	5.1	432
Jamal et al., 2009	*	MVA (45.5%)	Orbit (27.3%)	C2	Single cervical fracture	1.27:1	6.28	701
Lewis et al., 1985	*	MVA	Mandible	C5-C7	Subluxation and dislocation	2.7:1	19.3	982
Mulligan, 2010	*	MVA	Mandible,	C5-C7	*	*	4.9 to 8.0 %	1.3 million
Davidson, 1989	*	MVA (85%)	*	C2 C5-C7	Cervical spine injuries Dislocation Subluxation	75% male	1.3%	2,555
Jonathan Zelken, 2014	0–103	MVA (39%)	Mandible	C5-C7	Cervical spine injuries	77.6 Male	6.6%	4398
Mithani et al., 2009	35	MVA	Nasal Bone	*	Fracture/Dislocation	Male	9.7%	4786

* = Missing information.

Furthermore, several studies have reported that patients with an MFT and an associated CSI usually have a low Glasgow Coma Scale (Demetriades et al., 2000; Elahi et al., 2008; Holly et al., 2002; Sinclair et al., 1988) and that patients admitted with maxillofacial trauma and having a Glasgow Coma Scale of less than 8 is indicative of a CSI (Choonthar et al., 2016).

Limitations of this study include a limited amount of studies, improper data, missing information, inadequate documentation of the patient's records, absence of diagnostic tests, and prognosis and treatment methods among the included studies. Moreover, heterogeneous variables limited the possibility of a cumulative analysis.

5. Conclusion

The incidence of the association of CSIs with MFT has been low (12.13%). Nevertheless, in cases of an isolated mandibular trauma due to a severe blow presenting with a low Glasgow Coma Scale, maxillofacial surgeons should be at a high alert of an associated CSI

Ethical statement

Since this is a Systematic Review of the Literature an Ethical Approval was not obtained

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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