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CLINICAL & BASIC RESEARCH

The Impact of Traffic Law Enforcement Regulations on the Incidence and Severity of Maxillofacial Injuries

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abstract: ***Objectives:*** This study aimed to assess the effectiveness of the new traffic law enforcement regulations (TLERs) on the incidence and severity of maxillofacial injuries in Oman, as road traffic accidents (RTAs) are the main cause of facial injuries in Oman. ***Methods:*** A retrospective longitudinal analytic study was conducted at three tertiary care hospitals in Muscat, Oman. All patients with RTA-related maxillofacial injuries during a five-year period from January 2005 to December 2009 (before the new TLERs) and the five-year period from January 2015 to December 2019 (after the new TLERs) were included in the study. ***Results:*** A total of 1,127 patients were included in the study. Of these, 646 (57.3%) patients sustained RTA-related maxillofacial injuries before the implementation of the new TLERs compared to 481 (42.7%) after the introduction of TLERs. No significant gender-based difference was found between the two study periods. The incidence of injury before the implementation of the new TLERs was 22.7 per 100,000 population, which then reduced significantly to 11 per 100,000 after the TLERs were implemented. Overall, the mean facial injury severity score reduced significantly, from 3.2 to 2.3, after the implementation of the new TLERs. ***Conclusions:*** The findings of this study indicate that the newly introduced TLERs have resulted in a reduction in the incidence and severity of RTA-related maxillofacial injuries. Continuous improvement and reinforcement of TLERs will further help reduce the burden of these injuries to society in general and health services in particular.

Keywords: Law Enforcement; Traffic Accidents; Maxillofacial Injuries; Injury Severity Score; Oman.

Advances in Knowledge

- *This is the first Omani study that highlights the effectiveness of the new traffic law enforcement regulations in reducing the incidence and severity of road traffic accident (RTA)-related maxillofacial injuries in Oman.*
- *The findings of this study would be of interest to other countries, which may adopt the Omani approach to reducing the incidence and severity of RTA-related maxillofacial injuries.*

Application to Patient Care

- *The results of this study will help stakeholders and decision-makers to assess, review and improve current and future road safety strategies.*
- *The impact of human awareness and behavioural change is important in relation to road safety, and further studies need to focus on this area.*
- *As part of ensuring the effective implementation of traffic law enforcement regulations, the role of law enforcement in ensuring behavioural change and thus improving road safety should be considered.*

Globally, road traffic accidents (RTAs) are ranked as the 11th most common cause of death and the ninth most common cause of disabilities. In addition, the World Health Organization (WHO) has reported that more than 3,000 people die and 30,000 were injured or disabled every day because of RTAs.[1,2] In 2010, the Institute for Health Metrics and Evaluation reported that RTAs were the main cause of death in Oman.[3] Over the past five decades, Oman has experienced significant economical and sub-structural development, which has been accompanied by an exponential increase in its population, as well as the total number of vehicles.[4] RTAs have a great impact and result in multiple challenges that hinder the progressive development of the country and consume human, financial and health resources.[1–3,5] Governmental bodies, including the Royal Oman Police (ROP), Ministry of Transport, Ministry of Information and local municipalities, have been playing important roles in controlling and reducing the number and severity of these accidents by utilising information and communication technologies as well as by introducing different measures such as speed cameras, fines, penalty points and constructing safer highways (unpublished date).[6]

The maxillofacial region has prominent and mobile structures; thus, it is at risk of being injured during RTAs. Such injuries are serious and can cause

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severe blood loss, airway obstruction, facial deformity and, occasionally, death.[3,5,7] Studies have reported a marked reduction in the number and severity of maxillofacial injuries as an outcome of increased awareness within society as well as the amplification of traffic law enforcement regulations (TLERs).[5,7,8] In Oman, the implementation of the new TLERs, new road network and monitoring technologies have resulted in major improvements and upgrades, especially in the period between the end of 2009 and early 2014.[6] Assessing the impact of these measures and regulations on the incidence and severity of maxillofacial injuries is crucial to establishing their effectiveness and to marking the need for their continuous improvements. Therefore, this study was conducted to assess the incidence and severity of RTA-related maxillofacial injuries before and after the introduction of the new TLERs in Oman.

Methods

This retrospective longitudinal analytic study was carried out at three tertiary care hospitals: Al-Nahdha Hospital, Khoula Hospital and Sultan Qaboos University Hospital (SQUH), Muscat, Oman. These are the three main hospitals in Oman managing craniomaxillofacial injuries. The target patients were divided into two periods: first, before the introduction of the new TLERs (January 2005 to December 2009) and, second, after the introduction of TLERs (January 2015 to December 2019). Data were retrieved from two electronic healthcare systems (Alshifa 3 plus, Ministry of Health, for Al-Nahdha Hospital and Khoula Hospital and TrakCare® 2018, Unified Healthcare System, InterSystems Corporation, for SQUH). Data for the period before 2006 were gathered from the trauma log books that were used to manually record maxillofacial injuries before the start of the electronic healthcare systems. All patient files with a history of RTAs were reviewed.

The study inclusion criteria included all patients who presented to the three aforementioned hospitals with the diagnosis of maxillofacial injury as a consequence of RTA during the study periods. Study variables included gender, age, year of injury and diagnosis of the maxillofacial injury. All fractures were categorised according to the location: upper face (frontal bone and skull), mid-face (malar, maxillary, nasal bones and naso-orbito-ethmoid) and lower face (mandible). The injury was classified as an isolated injury when only one facial bone was involved and combined when it involved more than one facial bone. The facial injury severity score (FISS) was chosen to assess the severity of the injury. This index was first created by Bagheri *et al.* and has subsequently been used in multiple studies.[9] The FISS system categorises facial bones into three anatomical regions (upper face, mid-face and mandible) and each fracture line occurring in these areas is given an injury score according to the location, displacement and severity of the injury. Facial lacerations are also recorded as part of the FISS and the final score is calculated as the sum of each anatomical area sub-scores. Furthermore, the severity of the facial injury was categorised based on the FISS as mild (1–3), moderate (4–7) and severe (8–15), according to Alasseri *et al.*[10] A data collection sheet was designed using Microsoft Excel, Version 2019 (Microsoft Corp., Redmond, Washington, USA) to collect the study data and statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS), Version 22.0 (IBM Corp., Armonk, New York, USA). Descriptive statistics were used for the study variables and the data were expressed in terms of number, percentage, mean and standard deviation. Chi-squared tests were used for significance analysis between the study variables and the periods before and after the implementation of the new TLERs p=0.001 . A statistically significant result was set at P <0.05.

Before the commencement of the study, ethical approval was obtained from the respective research and ethics committees: the Research and Ethical Review & Approval Committee at the Centre of Studies & Research (MoH/CSR/20/16596), the Research and Ethics Committee at Al-Nahdha Hospital (MOH/ANH/RC/22/20) and the Medical Research Ethics Committee at Sultan Qaboos University (MREC #2319).

Results

A total of 5,444 patients with maxillofacial injuries were identified during the two study periods, of whom 1,127 met the study inclusion criteria of having sustained RTA-related maxillofacial injuries [Figure 1]. The mean age was 30.8 years for the first period (2005–2009) and 27.8 years for the second period (2015–2019), with the difference being statistically significant (P <0.01).

The maxillofacial injuries were more prevalent among men compared to women (78.6% versus 21.4%); however, in relation to the gender of those who sustained injuries, the difference between the two study periods was not statistically significant (P = 0.213) [Table 1].

The overall incidence of maxillofacial injuries per 100,000 population during the first and second periods was 22.7 and 11, respectively, indicating a significant

Table 1: Characteristics and demographic data of the study population (N = 1,127)

Variables	n (%)			*P* value
	2005–2009	2015–2019	Total	
RTA-related maxillofacial injuries among the total injuries*	646 (19.5)	481 (22.6)	1,127 (20.7)	
Gender				
Male	516 (79.9)	369 (76.7)	885 (78.5)	
Female	130 (20.1)	112 (23.3)	242 (21.5)	0.213
Total	646 (57.3)	481 (42.7)	1,127 (100)	
Age in years				
Mean	30.8	27.8	29.9	
Minimum	1	2	1	0.0001
Maximum	83	63	83	
Diagnosis				
Fracture of malar and maxillary bones	121 (18.7)	151 (31.4)	272 (24.1)	
Fracture of mandible	247 (38.2)	175 (36.4)	422 (37.4)	
Fracture of nasal bones	112 (17.3)	93 (19.3)	205 (18.2)	0.0001
NOE fracture	14 (2.2)	30 (6.2)	44 (3.9)	
Fracture of frontal bone	152 (23.5)	32 (6.7)	184 (16.3)	
Location of injury				
Upper face	152 (23.5)	30 (6.3)	182 (16.2)	
Mid-face	247 (38.2)	276 (57.4)	523 (46.4)	0.0001
Lower face	247 (38.2)	175 (36.4)	422 (37.4)	
Injury type				
Isolated	470 (72.8)	452 (94.0)	922 (81.8)	0.0001
Combined	176 (27.2)	29 (6.0)	205 (18.2)	

RTA = road traffic accident; NOE = naso-orbito-ethmoid.
**Calculated out of the total RTA-related injuries from each study period.*

Table 2: Comparison of facial injury severity scores before and after the implementation of the new traffic law enforcement regulations in relation to age and gender (N = 1,127)

Variable	n	Mean age ± SD	*P* value	Mean FISS score ± SD	*P* value
Year					
2005–2009	646	30.9 ± 13.3	0.0001	3.22 ± 2.15	0.0001
2015–2019	481	27.8 ± 12.5		2.31 ± 1.71	
Gender					
Male	885	29.4 ± 12.7	0.312	2.87 ± 2.01	0.237
Female	242	30.4 ± 14.2		2.69 ± 2.09	

SD = standard deviation; FISS = facial injury severity score.

reduction in these injuries after the implementation of the new TLERs ($P = 0.001$).

The majority of the encountered maxillofacial injuries were isolated fractures, accounting for 72.8% and 94% before and after the introduction of TLERs, respectively. Furthermore, these isolated fractures demonstrated an increase of 21.2% during the second period under study. On the contrary, combined injuries exhibited a significant decrease from 27.2% to 6%. This difference in the combined and isolated types of injuries between the two periods was statistically significant with a *P* value of <0.001 [Table 1].

Considering the location of the fractures, in both the study periods, an overall increase was observed in the occurrence of mid-facial fractures, while a reduction was noted in the number of upper and

Table 3: Facial injury severity score before and after the implementation of the new traffic law enforcement regulations

Year	Gender	n (%)			Total	*P* value
		Mild*	Moderate*	Severe*		
2005–2009	Male	310 (60.1)	189 (36.6)	17 (3.3)	516 (100)	
	Female	76 (58.5)	49 (37.7)	5 (3.8)	130 (100)	0.0001
	Total	386 (59.8)	238 (36.8)	22 (3.4)	646 (100)	
2015–2019	Male	289 (78.3)	75 (20.3)	5 (1.4)	369 (100)	
	Female	97 (87.4)	12 (10.8)	2 (1.8)	111 (100)	0.0001
	Total	386 (80.4)	87 (18.1)	7 (1.5)	480 (100)	
Total		772 (68.6)	325 (28.9)	29 (2.6)	1,127 (100)	0.0001

**Facial injury severity scores: Mild (1–3), moderate (4–7) and severe (8–15).*

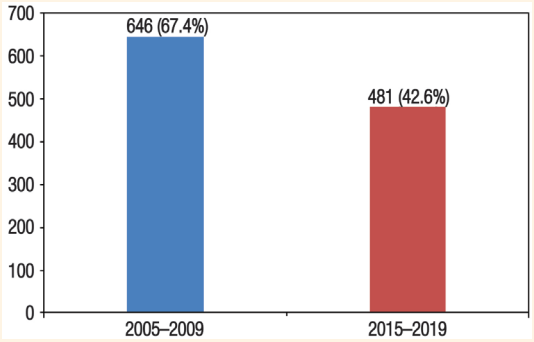

Figure 1: Road traffic accident-related maxillofacial injuries before and after the implementation of the new traffic law enforcement regulations (N = 1,127).

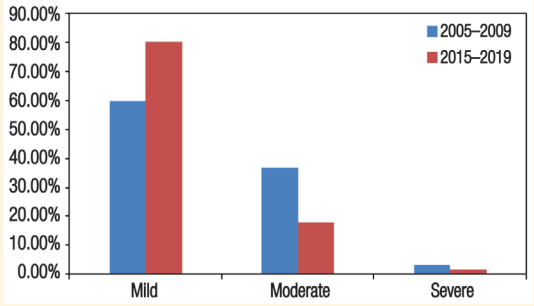

Figure 2: Facial injury severity score group categorisation before and after the implementation of the new traffic law enforcement regulations (N = 1,127).

lower facial fractures. Mandibular fracture was the most frequently encountered diagnosis, accounting for 37.4%, with naso-orbito-ethmoid fracture being the least encountered (4%) in both the study periods [Table 1].

Although the mean FISS score before the introduction of the new TLERs was mild at 3.22 ± 2.15, this further reduced to 2.31 ± 1.71 after the introduction of the new TLERs. This reduction in the mean scores between the two periods was statistically significant (P <0.001). There was no statistically significant difference in the mean FISS scores between the genders (P = 0.237) [Table 2]. The overall FISS categorisation was higher for mild injuries and low for severe injuries, accounting for 68.5% and 2.7%, respectively. However, there was a statistically significant decrease in the percentage of moderate and severe injuries after the introduction of the TLERs (P <0.001) [Figure 2 and Table 3].

Discussion

Oman is the second-largest country in land area and third in population size among the Gulf Cooperation Council (GCC) countries.[11] The income from oil revenue, coupled with guided government policies in development, has moved Oman to a prestigious position in several aspects and it was ranked the most 'improved nation' in the world in terms of development during the past five decades.[3,12] This rapid development was associated with a corresponding rapid rise in population and infrastructure, leading to a remarkable increase in the number of drivers and registered vehicles. The population in Oman increased from 2.8 million in 2009 to 4.6 million by the end of 2019. Similarly, the number of registered vehicles and drivers increased from 840,000 cars and 84,000 registered drivers at the end of 2009 to 1.7 million cars and 1.5 million drivers by the end of 2019.[11,13–15]

Over the past 10 years, through multiple governmental bodies, including the ROP, the Omani government has worked to further improve and enhance the road network and safety (unpublished data).[6,14] A national road safety committee was created in 2011 and October 18th was announced as the annual day of traffic safety. Furthermore, traffic safety symposia have been held annually since 2011, which also feature traffic safety competitions focusing on school audiences. Major media and reporting campaigns have been conducted over the years, promoting and focusing on road safety issues. All

media platforms have been utilised to this end, with the specific objectives of increasing awareness within the society, delivering educational programmes and encouraging behavioural changes in relation to road safety.[6] Furthermore, the ROP annually participate in and conduct activities as part of the GCC traffic week; these activities focus on raising public awareness and educating the public on issues related to road safety.[6,16] Furthermore, the Scientific Research Council of Oman has allocated annual road safety research funds and facilitated a liaison and consultancy agreement with the British Research and Transportation Centre to enhance traffic safety.[6] Aligning with the move towards better road safety in Oman, the new TLERs were reintroduced gradually from late 2009 to early 2014. These regulations were equally applied and strictly reinforced across Oman. The TLERs included strict traffic law regulations and penalties, road and speed monitoring technologies and other initiatives—including traffic rehabilitations and regular traffic awareness campaigns (unpublished data).[6,14,15] The present study, which addresses the impact of the new TLERs on maxillofacial injuries, was conducted five years after the implementation of the new regulations that aim to enhance public awareness and ensure the proper adoption and implementation of traffic laws.

This is the first study in Oman and the second in the GCC countries to assess the impact of TLERs on maxillofacial injuries. The present study looked at two five-year periods—one before and another after the introduction of the new TLERs. Hence, it was unique in covering a longer period before and after the implementation of TLERs when compared to the study by Alasseri *et al*.[10] The result of this study showed that the incidence of RTA-related maxillofacial injuries dropped from 22.7 to 11 per 100,000 people after the introduction of the new TLERs. This finding is consistent with those of other published works, indicating that more stringent traffic law regulations result in a significant reduction in RTAs and related injuries.[8,10,17–20]

The present study showed a male predominance in RTA-related maxillofacial injuries during both the study periods (mean = 78.6%). This finding is similar to previously published regional and international studies that reported that men are more commonly involved in RTA and account for up to 80% of these injuries.[9,10,18–20] Such high prevalence was attributed to the fact that men, being more empowered in society and engaged in more outdoor activities, were more likely to be involved in reckless driving compared to female drivers.[10,20] Furthermore, in the present study, the mean age of the involved patients was 29.9 years, which is consistent with the findings of published studies, indicating that this age group is associated with increased self-dependence, high activity and social interactions, which may increase their susceptibility to reckless driving and more road usage.[9,10,17–20]

Regarding the location of the injury, published data from Saudi Arabia reported that most maxillofacial injuries were in the lower face, with no reported occurrence in the upper face during both study periods—before and after the implementation of the Saher law enforcement system.[10] The present findings are in contrast to the study by Alasseri *et al*., in that before the implementation of TLERs, lower face and mid-face injuries had an equal occurrence, while after the adoption of TLERs, mid-face injuries were predominant, followed by lower face. This study also reports the occurrence of upper face injuries before and after the implementation of TLERs, with a statistically significant reduction in the occurrence of upper face injuries during the second study period. This important finding is in line with other published studies.[17–21] Considering the injury location based on the International Classification of Diseases diagnosis, the mandible was the most commonly involved maxillofacial bone during both study periods, a finding that supported other published scientific data.[9,10,17,20,21]

Assessing the severity of trauma is an important tool in estimating the risks of injury, predicting survival probability and outcome, planning for emergency and definitive treatment, predicting health costs and determining hospital length of stay (LOS).[10,21,22] For this purpose, many trauma severity scoring systems have been proposed and adopted over the past few decades.[21] The Abbreviated Injury Scale, the Injury Severity Score (ISS) and the Trauma and Injury Severity Score (TRISS) were among the first trauma severity scoring systems adopted in the 1970s and 1980s and have since undergone various revisions and updates.[23–26] In 1997, Osler *et al*. revised the ISS system and proposed the New Injury Severity Score (NISS), which eliminated the shortcomings of ISS and made it more simple and accurate to record.[27]

The main drawback of these trauma systems is that they were primarily designed to assess general trauma and, in particular, survival but not disability, prognostic outcome, cost of treatment or LOS.[10,21] Proper assessment of the severity of maxillofacial trauma requires accurate recording of the injury type, location, functional abnormalities and disability implications.[9,10,22,23] To address this area of trauma, newer severity scoring systems were introduced, including the Maxillofacial Injury Severity Score (MFISS), introduced by Zhang *et al*. in 2006; the Facial Injury Severity Score (FISS) introduced by Bagheri *et al*. in 2006; and the MISS introduced by Shi *et al*.

in 2008.[9,23,28] Recently published work by Chen *et al.* comparing four different maxillofacial trauma severity scoring systems showed that the MFISS was a better scoring system. It has also proved to be a reliable system in assessing trauma severity, treatment plan, prognosis prediction and outcome and in assisting epidemiological and clinical studies on maxillofacial trauma.[22] However, the MFISS has multiple inherent deficiencies, which also exist within the other severity systems, including an inability to accurately record the severity of mid-face fractures and functional impairments.[22,23] The MFISS is also a more complex system and demands multiple data entries compared to the FISS. Accordingly, for this study, the FISS was used to evaluate trauma severity pre- and post-implementation of the new TLERs, without the need for analysing the outcome, prognosis or treatment needs. Furthermore, the FISS is a simple system to use, as it requires far less data entry in comparison to the MFISS and MISS systems and has been validated as a reliable system for recording maxillofacial trauma severity.[6,7,21]

The FISS is a simple maxillofacial severity scoring scale that was designed and introduced by Bagheri *et al.* in 2006 for maxillofacial trauma research purposes and has since been used in multiple international studies to record maxillofacial trauma severity.[9,10,22] The current study showed that there was a statistically significant reduction in FISS score from 3.2 to 2.3 after the implementation of the new TLERs, which contradicts the findings of Alasseri *et al.*, wherein the mean FISS changed from 3.2 to 3.5 after the introduction of the Saher system.[10] Although their sample size was small, Alasseri *et al.* showed that a reduction in the FISS injury subtype scores and a reduction in the overall incidence of RTA-related maxillofacial injuries from 58.9% to 41.4% occurred after the implementation of the new traffic regulations in Saudi Arabia.[10] The present study findings are in line with previously published studies that highlight the overall benefits of the enforcement and adoption of strict traffic law regulations in reducing the incidence of RTA-related trauma.[7,8,10,17–20] Many developed countries, including countries in North America and Europe, have succeeded in reducing the incidence of RTAs from over 30% to 3–8% over a few decades by investing in human education, research and strict traffic regulations.[7,8,16,20,29,30]

Previously published data from different GCC countries reported that 51–63% of the maxillofacial injuries are RTA-related, which indicates that it is the major aetiological factor in these injuries. These reports have identified the need for collaborative work to reduce this relatively high incidence and have recommended adopting multiple measures that focus on improving public awareness, education, road network and safety and more strict traffic regulations.[16,17,20,31] The present study has demonstrated the benefits of adopting the new TLERs that have led to a significant reduction in the incidence of RTA-related maxillofacial injuries in Oman from 53% and 63% before introducing the new TLERs, as reported by Bakathir *et al.* and Al-Hashmi *et al.* in 2008, to 19.5% and 22.6% after the introduction of the TLERs.[16,31] Furthermore, the significant increase in isolated maxillofacial fractures and the significant decrease in combined injuries are indicative of Oman's achievement and success in the implementation and reinforcement of TLERs.

This retrospective analysis had a few limitations and inherent drawbacks, including missing and limited sources of data and failure to record other associated injuries that would serve as an additional measure of the severity of the injury. This national study is not fully comprehensive, as it lacks data from other smaller maxillofacial surgery units, such as the Armed Forces Hospital and the three regional hospitals in Sohar, Salalah and Ibri that have started managing maxillofacial trauma since 2016. Further studies incorporating detailed maxillofacial trauma assessment, treatment, outcome, cost and LOS will be important in assessing the impact of RTA-related maxillofacial injuries on the healthcare system in Oman.

Conclusion

The new Omani TLERs were effective in reducing the incidence and severity of RTA-related maxillofacial injuries. However, additional work is required for the continued improvement and reinforcement of TLERs, which can further reduce the incidence and burden of RTA-related injuries in Oman. The findings of this study should help all stakeholders assess and review current and future road safety strategies. The role of human awareness and behaviour is important in relation to road safety and further studies need to focus on this area.

AUTHORS' CONTRIBUTION

AH, AB and AA conceptualised and designed the study. AA obtained ethical approval for the study. AH, AB and SH supervised the work. AA, KH and SR collected the data. AA and AB drafted the manuscript. MI edited the manuscript. All authors approved the final version of the manuscript.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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