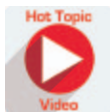


The Effects of Motorcycle Helmet Legislation on Craniomaxillofacial Injuries

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Background: Motorcycle helmet legislation has been a contentious topic for over a half-century. Benefits of helmet use in motorcycle trauma patients are well documented. In 2012, Michigan repealed its universal motorcycle helmet law in favor of a partial helmet law. The authors describe the early clinical effects on facial injuries throughout Michigan.

Methods: Retrospective data from the Michigan Trauma Quality Improvement Program trauma database were evaluated. Included were 4643 motorcycle trauma patients presenting to 29 Level I and II trauma centers throughout Michigan 3 years before and after the law repeal (2009 to 2014). Demographics, external cause of injury codes, *International Classification of Diseases, Ninth Revision* diagnosis codes, and injury details were gathered.

Results: The proportion of unhelmeted trauma patients increased from 20 percent to 44 percent. Compared with helmeted trauma patients, unhelmeted patients were nearly twice as likely to sustain craniomaxillofacial injuries (relative risk, 1.90), including fractures (relative risk, 2.02) and soft-tissue injuries (relative risk, 1.94). Unhelmeted patients had a lower Glasgow Coma Scale score and higher Injury Severity Scores. Patients presenting after helmet law repeal were more likely to sustain craniomaxillofacial injuries (relative risk, 1.46), including fractures (relative risk, 1.28) and soft-tissue injuries (relative risk, 1.56). No significant differences were observed for age, sex, Injury Severity Score, or Glasgow Coma Scale score ($p > 0.05$).

Conclusions: This study highlights the significant negative impact of relaxed motorcycle helmet laws leading to an increase in craniomaxillofacial injuries. The authors urge state and national legislators to reestablish universal motorcycle helmet laws. (*Plast. Reconstr. Surg.* 139: 1453, 2017.)

Motorcyclists are 30 times more likely to die and five times more likely to be injured when compared mile for mile to passenger car occupants.¹ Motorcycle helmets have been shown to prevent nearly 40 percent of fatal injuries and 13 percent of nonfatal serious injuries.¹⁻³ However, as many as one-third of motorcycle riders still do not wear helmets, with a larger percentage

riding unhelmeted in states without universal helmet laws.³ The effects of motorcycle helmet legislation on helmet use, patient injuries, and outcomes have been demonstrated.²⁻⁹ However, few to no data are available evaluating the effects of motorcycle helmet laws on craniomaxillofacial trauma.

Complex facial injuries are common among motorcycle trauma patients and are over twice as

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Received for publication August 24, 2016; accepted October 6, 2016.

Presented at the 55th annual Midwest Association of Plastic Surgeons meeting, in Chicago, Illinois, April 30, 2016; and at the 29th biennial Michigan Academy of Plastic Surgeons meeting, on Mackinac Island, Michigan, July 24 through 27, 2016.

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DOI: 10.1097/PRS.0000000000003370

Disclosure: The authors have no financial interest to declare in relation to the content of this article.

A "Hot Topic Video" by Editor-in-Chief Rod J. Rohrich, M.D., accompanies this article. Go to PRSJJournal.com and click on "Plastic Surgery Hot Topics" in the "Digital Media" tab to watch. On the iPad, tap on the Hot Topics icon.

likely in unhelmeted patients.^{10–12} Although most facial injuries are not immediately life threatening, patients sustaining complex facial injuries have been shown to have poorer health outcomes and greater injury-related disability preventing employment.¹³

The National Highway Safety Act was signed into law in 1966 mandating that all states enact specific safety standards to continue receiving federal highway funding. Included in the legislation was the requirement for universal motorcycle helmet laws. In 1976, Congress amended the act, allowing states more flexibility in the implementation of helmet regulations.⁹ On April 13, 2012, the state of Michigan repealed their universal helmet law in favor of a partial law.

We hypothesized that the repeal of universal helmet laws would lead to increased rates of craniomaxillofacial trauma. To test our hypothesis, we analyzed motorcycle trauma patients presenting to trauma centers in the state of Michigan. This article describes the rates and patterns of craniomaxillofacial injuries in patients presenting before and after repeal of Michigan's universal helmet law. In addition, we assessed the craniomaxillofacial injuries in helmeted and nonhelmeted riders.

PATIENTS AND METHODS

To investigate the effect of motorcycle helmet legislation on craniomaxillofacial injuries, we conducted a retrospective review of the Michigan Trauma Quality Improvement Program's trauma database. This database captures clinical information from trauma patients admitted to 29 Level I and II trauma centers throughout the state of Michigan. This study was performed in accordance with the Declaration of Helsinki. After receiving approval from the Spectrum Health Institutional Review Board, data were obtained for the 3-year periods before (January 1, 2009, to April 12, 2012) and after (April 13, 2012, to December 31, 2014) repeal of the universal helmet law.

The database, before screening for inclusion and exclusion criteria, contained records for

96,636 patients. Motorcycle trauma patients were selected using the *International Classification of Diseases, Ninth Revision, Clinical Modification* External Cause of Injury Codes (E-Codes) (E810 to E819 and E820 to E825, series 0.2 and 0.3). Patients with keywords pertaining to off-road vehicles, such as all-terrain vehicles and dirt bikes, and patients younger than 18 years were excluded. Data collected included age, sex, helmet status, blood alcohol content, and Injury Severity Score. Craniomaxillofacial injuries were identified using *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis codes for fractures and soft-tissue injuries. Facial fracture codes for nasal bone fractures (802.0 and 802.1), malar fractures (802.4 and 802.5), orbital fractures (802.6 to 802.8), and mandibular fractures (802.20 to 802.39) were included. Soft-tissue codes identified included facial lacerations (873.2 to 873.7), facial abrasions (910), and facial contusions (920).

Statistical Analysis

Data were analyzed using STATA v14.1 (StataCorp LP, College Station, Texas). Descriptive statistics were calculated. Quantitative data are expressed as the mean \pm SD, whereas nominal data are expressed as a percentage. Comparisons between groups for quantitative variables were performed using the *t* test. Nominal variables were evaluated using the chi-square test. Relative risk was calculated on nominal variables. Statistical significance was assessed at a value of $p < 0.05$.

RESULTS

Data from 4643 motorcycle trauma patients were included. Eighty-seven percent were men, and the average age was 43.7 ± 14.8 years (mean \pm SD). One thousand nine hundred seventy motorcycle trauma patients were included from January 1, 2009, to April 12, 2012, and 2673 patients after repeal (April 13, 2012, to December 31, 2014) were included. Demographic and clinical data for both cohorts are listed in Tables 1 and 2. No differences

Table 1. Demographic and Clinical Data

	Universal Helmet Law		Partial Helmet Law		<i>p</i>
	Value (%)	No.	Value (%)	No.	
Age	43.6 \pm 14.6 yr	1970	43.7 \pm 14.9 yr	2673	0.785
Sex (% males)		1701/1969 (86.4)		2348/2673 (87.8)	0.143
BAC					
Any alcohol (>0)	136 \pm 95.6	422	131 \pm 103.3	733	0.436
Intoxicated (>79)	182 \pm 77.2	291	192 \pm 81.8	461	0.118
ISS	15.3 \pm 11.3	1970	14.7 \pm 10.6	2673	0.062

BAC, blood alcohol content (mg/dl); ISS, Injury Severity Score.

Table 2. Demographic and Clinical Data

	Helmeted Patients		Unhelmeted Patients		<i>p</i>
	Value	No.	Value	No.	
Age	43.9 ± 14.3 yr	2138	43.6 ± 15.2 yr	1317	0.602
Sex (% male)		1861/2138 (87.0)		1167/1317 (88.6)	0.174
BAC					
Any alcohol (>0)	111 ± 94	414	149 ± 103	493	< 0.0001
Intoxicated (>79)	178 ± 73	232	199 ± 80	348	0.002
ISS	14.3 ± 9.8	2138	15.2 ± 11.7	1317	0.010

BAC, blood alcohol content (mg/dl); ISS, Injury Severity Score.

in age, sex, Injury Severity Score, or blood alcohol content were found between the two groups. When helmeted patients were compared with unhelmeted riders, no differences were seen with respect to age and sex. Unhelmeted patients had higher mean blood alcohol content compared with helmeted riders. After helmet law repeal, the proportion of nonhelmeted trauma patients presenting to Michigan trauma centers increased, from 20 percent to 44 percent (*p* < 0.0001) (Fig. 1).

Patients sustaining any craniomaxillofacial injury, including fractures and soft-tissue injuries, increased significantly after repeal of the universal helmet law (*p* < 0.0001), with a relative risk of 1.46 (Tables 3 and 4). When analyzed separately, the rate of facial fractures and facial soft-tissue injuries both showed a significant increase. Unhelmeted patients were nearly twice as likely to present with craniomaxillofacial trauma; this included both facial fractures and soft-tissue injuries.

Trauma patients presenting after repeal were more likely to sustain malar fracture (*p* = 0.002), facial lacerations (*p* < 0.0001), facial abrasions (*p* = 0.006), and facial contusions (*p* < 0.0001) compared with those presenting during the universal helmet law (Tables 5 and 6). All types of craniomaxillofacial injuries analyzed occurred more

frequently in the unhelmeted cohort, relative to helmeted patients.

DISCUSSION

This study demonstrates a significant increase in craniomaxillofacial injuries in motorcycle trauma patients after repeal of Michigan’s universal helmet law. Several studies have shown an increased incidence of craniomaxillofacial injuries in unhelmeted riders, but none have shown the correlation between weakened motorcycle helmet laws and increased craniomaxillofacial injuries.^{10–12}

Dramatic decreases in helmet use have been described following helmet law repeal.^{2,3,8,14} This study confirms these findings, showing a greater than two-fold increase in unhelmeted motorcycle trauma patients. Moreover, our data identify a substantial increased risk of craniomaxillofacial injuries in unhelmeted patients, providing a likely cause for the increase in facial injuries after the repeal. This finding is well documented in the literature.^{10–12} The risk for alcohol intoxication acting as a confounder remains a concern. We did note a higher blood alcohol content in unhelmeted patients compared with helmeted riders. However, no difference was seen when comparing patients presenting before and after the universal helmet law was rescinded. Furthermore, other large series have found an increase in injuries in unhelmeted patients even after controlling for multiple confounding variables, such as alcohol and drug use.^{12,15}

The results from this study also indicate an increase in certain patterns of facial injuries following the change in Michigan’s helmet law. We noted a significant increase in malar fractures and facial soft-tissue injuries, including lacerations, contusions, and abrasions. Other studies have shown increases in multiple injury patterns in unhelmeted patients, including fractures and soft-tissue injuries. Christian et al. reported similar findings to ours, with a higher proportion of unhelmeted motorcyclists sustaining malar fractures and soft-tissue injuries. They also noted an increase in

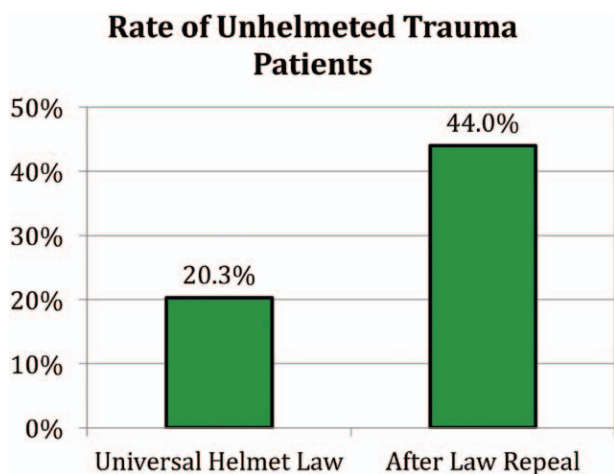


Fig. 1. Percentage of unhelmeted motorcycle trauma patients.

Table 3. Facial Injury Comparisons

	Universal Helmet Law (%)	Partial Helmet Law (%)	<i>p</i>	Relative Risk	95% CI
CMF trauma (bone and soft tissue combined)	25.5	37.2	<0.0001	1.46	1.33–1.59
Facial fractures	12.2	15.1	<0.0001	1.28	1.11–1.48
Soft-tissue injuries	20.4	31.8	<0.0001	1.56	1.40–1.73

CMF, craniomaxillofacial.

Table 4. Facial Injury Comparisons

	Helmeted Patients (%)	Unhelmeted Patients (%)	<i>p</i>	Relative Risk	95% CI
CMF trauma (bone and soft tissue combined)	26.3	49.8	<0.0001	1.90	1.73–2.07
Facial fractures	10.9	21.9	<0.0001	2.02	1.72–2.36
Soft-tissue injuries	22.1	42.9	<0.0001	1.94	1.75–2.15

CMF, craniomaxillofacial.

Table 5. Comparison of Specific Facial Injuries

	Universal Helmet Law (%)	Partial Helmet Law (%)	<i>p</i>	Relative Risk	95% CI
Nasal bone fractures	5.8	6.8	0.181	1.17	0.93–1.46
Orbital fractures	6.4	7.6	0.116	1.19	0.96–1.47
Malar fractures	6.0	8.5	0.002	1.41	1.14–1.75
Mandibular fractures	2.3	2.3	0.972	0.99	0.68–1.45
Facial lacerations	10.9	17.7	<0.0001	1.62	1.40–1.90
Facial abrasions	7.0	9.2	0.006	1.32	1.08–1.61
Facial contusions	5.2	11.1	<0.0001	2.26	1.81–2.80

Table 6. Comparison of Specific Facial Injuries

	Helmeted Patients (%)	Unhelmeted Patients (%)	<i>p</i>	Relative Risk	95% CI
Nasal bone fractures	5.1	9.0	<0.0001	1.74	1.36–2.24
Orbital fractures	5.0	11.3	<0.0001	2.28	1.80–2.90
Malar fractures	5.4	12.5	<0.0001	2.33	1.85–2.93
Mandibular fractures	1.8	3.3	0.005	1.83	1.20–2.80
Facial lacerations	12.8	23.0	<0.0001	1.89	1.63–2.19
Facial abrasions	7.4	11.8	<0.0001	1.59	1.29–1.97
Facial contusions	6.36	16.25	<0.0001	2.55	2.08–3.13

orbital fractures within their series.¹⁰ Crompton et al. evaluated 46,362 motorcycle trauma patients for facial injuries using the National Trauma Data Bank. They reported a significant increase in mandibular, malar, nasal, and orbital fractures in addition to increased soft-tissue injuries.¹²

Although there are no published data on the effects of motorcycle helmet legislation on facial injuries, there are several publications evaluating the effects of helmet laws and helmet law change on patient outcomes and injury severity.^{2,3,5,6,14} These studies show dramatic effects of helmet laws on mortality, traumatic brain injuries, hospital admission, critical care use, hospital charges, and injury severity. Despite this established body of evidence

supporting the clear benefits of motorcycle helmet use and motorcycle helmet laws, states continue to weaken or rescind their helmet legislation.

Our study is limited by the fact that it is retrospective. In addition, the nature of the Michigan Trauma Quality Improvement Program database is such that data are collected from multiple sources with nonuniform coding practices and standards of care. Furthermore, not all variables were present for all patients in the database. However, all data were gathered from the same database, and any irregularities should be equally represented in all groups. Data from persons not injured severely enough for admission to a reporting trauma center or those that died on scene were not included in

the database or analysis. Details about helmet type were also not available. Other limitations include the lack of *International Classification of Diseases, Ninth Revision, Clinical Modification* codes for specific upper face fractures, such as frontal sinus fractures. These types of upper face injuries have previously been shown to occur more often in unhelmeted patients and would have likely increased the calculated incidence and relative risk in this study.¹⁶

CONCLUSIONS

We have shown a significant increase in facial injuries in patients presenting to Michigan trauma centers after law repeal. The data presented in this article highlight yet another significant negative impact of weakened motorcycle helmet laws. This study suggests that wearing a motorcycle helmet could decrease the risk of facial trauma by half, and the reinstatement of a universal helmet law could decrease facial injuries by over 30 percent. We urge state and national legislators to reestablish universal motorcycle helmet laws.

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ACKNOWLEDGMENTS

The authors would like to acknowledge Tracey Koehler, Ph.D., and the Michigan Trauma Quality Improvement Program for assistance with this project.

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