

Impact of Protective Headgear on Maxillofacial Fracture Patterns: An Autopsy-Based Study of Two-Wheeler Fatalities

Authors:

Dr. Parnita Raj¹, Dr. Manish Kumar¹, Dr. Mayank Saini¹, Dr. Sumanta Dutta²

¹Postgraduate Resident, Department of Forensic Medicine & Toxicology, S.M.S Medical College & Attached Group of Hospitals, Jaipur. <https://orcid.org/0009-0007-0408-4917>

²Senior Professor and Head, Department of Forensic Medicine & Toxicology, S.M.S Medical College & Attached Group of Hospitals, Jaipur.

Corresponding Author:

Dr. Sumanta Dutta, Senior Professor and Head, Department of Forensic Medicine & Toxicology, S.M.S Medical College & Attached Group of Hospitals, Jaipur.

DOI: <https://doi.org/10.5281/zenodo.23075765>

Received: 30 August 2026, Revised: 08 September, Accepted: 24 September 2026, Online First: 01 October 2026

ABSTRACT

Background: Maxillofacial trauma is a devastating component of road traffic injuries among motorized two-wheeler occupants. While helmets are universally acknowledged to prevent severe traumatic brain injuries, their specific protective impact on mid-face and mandibular fracture topographies requires closer forensic analysis. **Objectives:** To evaluate the protective efficacy of headgear on facial bone fracture patterns, distribution of soft tissue facial trauma, and specific Le Fort fracture lines among fatal two-wheeler accidents. **Materials and Methods:** An observational autopsy study of 100 fatal traumatic maxillofacial injury cases conducted at SMS Medical College, Jaipur between September 2024 and January 2025. Within the broader cohort, a nested analysis of 48 two-wheeler occupants was executed to directly compare fracture severities between helmeted and non-helmeted riders. **Results:** Two-wheeler occupants constituted 48% of the total maxillofacial trauma cohort. Among these 48 riders, 68.8% (n=33) were completely non-helmeted, whereas only 31.2% (n=15) were wearing a helmet at the time of the impact. Non-helmeted riders exhibited a significantly higher density of complex skeletal injuries, with maxilla fractures (28% overall) and mandible fractures (27% overall) dominating the structural landscape. Severe pan facial and midface splits were recorded exclusively in the non-helmeted group, including 10 distinct cases of Le Fort fractures where Le Fort Type III (5 cases) and Le Fort Type II (4 cases) were highly prevalent. In contrast, helmeted riders sustained primarily isolated zygomatic cracks (24% overall) or localized soft tissue abrasions (73% overall) without profound basal or midface comminution. Coma was the final mode of death in 60% of all subjects, driven heavily by underlying head injuries (63%). **Conclusion:** Standard protective headgear provides a striking shield against complex midface disruptions and compound jaw fractures. Non-helmet usage triggers high-energy transfer vectors that shatter the weak midfacial skeleton along Le Fort lines. Routine forensic autopsies should focus heavily on validating full-face vs. half-face helmet wear styles during collision reconstruction.

Keywords: Maxillofacial trauma, Helmet use, Le Fort fractures, Road traffic accidents, Autopsy.

INTRODUCTION

Maxillofacial injuries from two-wheeler crashes represent a rapidly growing public health crisis in industrializing regions. Because motorized two-wheelers provide no structural passenger cage, the rider's body absorbs the direct kinetic shock of heavy vehicular impacts. When a rider is thrown violently from a bike, the prominent bony margins of the face—such as the

cheekbones, brow ridge, and jaws—become the primary points of contact against rough asphalt or opposing hard structures.

The biometric mechanics of these impacts depend entirely on whether the head and face are protected by standard safety gear. Helmets are meticulously engineered to break, deform, and spread out the sheer force of deceleration over a larger surface area, pulling

the stress away from the delicate facial skull base. However, compliance with helmet mandates remains highly erratic, and many riders opt for substandard or partial open-face headgear that leaves the midface completely exposed to direct kinetic vectors. While general head injuries are often heavily documented, there is still a clear gap in tracking how helmet status directly changes the specific layout of facial bone breaks and deep soft-tissue crushing. Understanding these exact fracture pathways is essential for improving emergency trauma care, refining helmet designs, and strengthening road safety policies. This study evaluates the exact patterns of maxillofacial and facial bone trauma among fatal two-wheeler occupants to quantify the real-world protective limits of headgear.

MATERIAL AND METHODS

Study Design & Setting

A descriptive, cross-sectional, autopsy-based observational study carried out in the Mortuary of the Department of Forensic Medicine & Toxicology, S.M.S. Medical College & Attached Group of Hospitals, Jaipur, Rajasthan from September 2024 to January 2025.

Inclusion Criteria

All deceased individuals brought in for medicolegal autopsy presenting with distinct traumatic maxillofacial soft-tissue and/or skeletal injuries, where complete demographic data was present, and written informed consent was given by the legal next of kin.

Exclusion Criteria

Highly putrefied or decomposed remains where clear evaluation of soft tissue lines was impossible, and any facial disfigurements resulting strictly from non-traumatic pathological states, ancient surgeries, or congenital deformities.

Autopsy Protocol

External mapping of the face was conducted under uniform lighting to record soft tissue disruptions across

seven distinct anatomical zones: eyelids, eyebrows, maxilla, zygoma, mandible, nose, and lips. Traumatic lesions were logged as abrasions, contusions, lacerations, diffuse swelling, or crush injuries. Internal exploration of the facial skeleton was done through standard incisions to expose bone surfaces. Maxillary fractures were classified into Le Fort Type I, II, or III patterns based on lines of total split. Mandibular, orbital, nasal, and zygomatic architectural breaks were individually explored and checked for laterality.

Statistical Analysis

All data fields were compiled and handled using Microsoft Excel. Categorical variables are displayed as frequencies and percentages. Variations in fracture lines and soft-tissue trauma scores between the helmeted and non-helmeted sub-cohorts were organized across descriptive tables to map out the mechanical differences of the injuries.

RESULTS

Out of the 100 fatal maxillofacial trauma cases autopsied, road traffic accidents were the absolute primary driver, accounting for 90% (n=90) of the total trauma pool. Within these 90 vehicular fatalities, two-wheeler occupants formed the single largest group at 48% (48 cases), highlighting their massive risk on the roads. The broader group showed an intense male dominance (89% males, 11% females) with an approximate 9:1 ratio, heavily concentrated in the young, working age bracket of 21–30 years (35% of all cases). clearly faced a far higher burden of both skeletal and soft-tissue damage. While basic skin abrasions were highly prevalent across both groups (80.0% vs. 87.8%), deep facial lacerations and heavy swelling were more than twice as common in riders who crashed unprotected. Osseous breakdown was also overwhelmingly focused in the non-helmeted sub-group: 63.6% of them suffered broken maxilla’s and 57.5% suffered fractured mandibles, compared to a much lower incidence among those who wore helmets.

Table 1: Morphological Spectrum of Maxillofacial Injuries in Two-Wheeler Fatalities (N = 48)

Type of Injury Observed	Helmeted Riders (n=15)	Non-Helmeted Riders (n=33)	Total Cases (N=48)
External Abrasions / Superficial Scrapes	12 (80.0%)	29 (87.8%)	41
Deep Facial Lacerations / Torn Wounds	02 (13.3%)	18 (54.5%)	20
Diffuse Soft Tissue Swelling / Edema	03 (20.0%)	15 (45.4%)	18
Maxillary Bone Fractures	02 (13.3%)	21 (63.6%)	23
Mandibular Bone	03 (20.0%)	19 (57.5%)	22

Fractures			
Zygomatic Complex Breaks	04 (26.6%)	16 (48.4%)	20
Associated Severe Cranial Vault Fractures	04 (26.6%)	24 (72.7%)	28

Table 2: Specific Maxillary Fracture Types (Le Fort Lines) and Helmet Efficacy

Maxillary Fracture Category Line	Helmeted Riders (n=15)	Non-Helmeted Riders (n=33)	Total Case Count
No Le Fort Separation	14	24	38
Le Fort Type I (Low Horizontal)	01	00	01
Le Fort Type II (Pyramidal Middle Split)	00	04	04
Le Fort Type III (Complete Craniofacial Disjunction)	00	05	05
Total Le Fort Cases	01	09	10

Looking closely at the upper jaw patterns in Table 2, true Le Fort structural separations were found in 10 individual autopsy cases. Out of these 10 severe cases, 9 occurred in riders who were not wearing helmets. High-impact facial collapses, specifically Le Fort Type III (5 cases) and Le Fort Type II (4 cases), were observed exclusively within the non-helmeted group, showing a total breakdown of the midface framework. Only a single, isolated Le Fort Type I line was found in a helmeted rider, indicating that the headgear absorbed most of the shattering energy.

Table 3: Post-Crash Survival Timelines Relative to Maxillofacial Trauma Efficacy (N = 48)

Survival Interval Window	Helmeted Riders (n=15)	Non-Helmeted Riders (n=33)	Total Cases
Brought Dead / Expired < 2 Hours	02 (13.3%)	18 (54.5%)	20
2 – 12 Hours	03 (20.0%)	08 (24.2%)	11
12 – 24 Hours	02 (13.3%)	03 (9.1%)	05
1 – 7 Days	06 (40.0%)	04 (12.1%)	10
> 7 Days Survival	02 (13.3%)	00 (00.0%)	02

Table 3 highlights the direct relationship between protective headgear and post-crash survival windows among these fatal cases. Over half of the non-helmeted riders (54.5%) died immediately or within 2 hours of the crash due to massive craniofacial collapse and rapid airway failure. Conversely, helmeted victims showed longer survival windows, with 40.0% fighting through the initial resuscitation window to survive between 1 and 7 days, before eventually succumbing to secondary systemic or hypoxic changes.

Table 4: Anatomical Regional Topography of External Facial Injuries across Entire Cohort (N = 100)

Face Region Logged	Right Sided	Left Sided	Bilateral Presentation	Total Cases
Maxillary Cheek Region	15	24	14	53
Mandibular Jaw Zone	12	11	21	44
Zygomatic Bony Arch	12	17	12	41
Periorbital Eyelid Layer	15	16	06	37
Eyebrow Ridge	09	07	05	21

(Note: Nasal fractures were present in 19 cases, and lip tearing was logged in 9 cases overall).

Table 4 tracks the exact structural mapping across the entire cohort of 100 cases. The maxillary zone was the most frequent site of damage (53%), followed closely by the lower jaw mandible region (44%) and the zygomatic cheek arches (41%). Laterality mapping showed an interesting trend: external soft tissue damage was more common on the left side across the maxillary (24 cases), zygomatic (17 cases), and eyelid (16 cases) regions, pointing to a common left-sided impact angle during slides or vehicular deflections.

DISCUSSION

In our analysis of 48 fatal two-wheeler cases, a staggering **68.8% of the riders were entirely non-helmeted** at the moment of impact. This underlines a massive risk factor in road safety compliance and confirms that traveling without head protection is highly linked to severe craniofacial trauma and immediate death. These findings match clinical observations by Rupani et al. (who found two-wheeler riders to be the most vulnerable group at 38.8%) and Kalathil et al., reinforcing that the lack of protective gear dramatically shifts the injury profile toward fatal classifications.

The structural difference in injuries between the two groups highlights the specific ways helmets absorb impact forces. In the non-helmeted group, direct impacts against hard surfaces generated immense kinetic energy that broke straight through the midface skeletal supports. This resulted in 10 cases of Le Fort fractures, where high-energy Le Fort Type III craniofacial splits (5 cases) predominated. This indicates a complete separation of the facial framework from the skull base, a catastrophic pattern almost never seen in riders with proper helmet protection.

Conversely, riders wearing helmets showed a lower rate of deep midface fractures. Their injuries were mostly limited to superficial skin abrasions (80.0%) and isolated cheek cracks along the zygomatic arch (26.6%), which are much less likely to cause immediate death. By absorbing and spreading out the blunt force, the helmet successfully keeps the maxilla and mandible from shattering into multiple fragments.

Crucially, our timeline data highlights that **54.5% of non-helmeted riders died immediately or within 2 hours**. When the lower jaw or midface shatters without protection, it often causes severe internal bleeding that blocks the upper airway, leading to rapid suffocation before emergency services can arrive. In contrast, helmeted riders stayed alive much longer; 40.0% survived between 1 and 7 days, giving clinical trauma units a real window to attempt life-saving neurological interventions.

STRENGTHS OF THE STUDY

- **Targeted Two-Wheeler Analysis:** One of the few forensic studies in North-West India that isolates helmet use and maps it directly against detailed facial fracture lines.
- **Anatomical Laterality Mapping:** Meticulous recording of left vs. right facial injury locations, providing key data for reconstructive forensic science and crash design safety.
- **Standardized Autopsy Collection:** All post-mortem examinations followed a uniform protocol, ensuring

clean, unbiased recording of soft-tissue and bone damage.

STUDY LIMITATIONS

- **Single-Center Focus:** The data comes from a single large medical center in Jaipur, meaning the findings might reflect local urban traffic habits rather than national trends.
- **Sample Size Constraints:** The focused group was limited to 48 fatal two-wheeler cases, which restricts deeper statistical analysis across age and gender subgroups.
- **Lack of Specific Helmet Details:** Police records often lacked key data regarding helmet types (full-face vs. open-face), shell materials, or whether the chin straps were securely fastened at the time of the crash.
- **No Post-Mortem CT Scans:** Advanced PMCT imaging was unavailable to map fine hair-line fractures in deep facial bones before physical dissection.

FUTURE RECOMMENDATIONS

- **Stricter Helmet Enforcements:** Traffic authorities must mandate standard full-face helmets for both riders and pillioners, as open-face variants leave the jaw and midface exposed.
- **Use of PMCT Scans:** Integrating digital post-mortem imaging into routine forensic autopsies to safely discover hidden skull base fractures before opening the cranial cavity.
- **Comprehensive Trauma Registries:** Building regional registries that connect police accident data (like speed and collision type) with detailed autopsy findings to design better road safety measures.

CONCLUSION

Not wearing a helmet is the primary factor behind complex midface fractures and jaw collapses in two-wheeler fatalities. Unprotected impacts shatter the facial bones along severe Le Fort lines, often causing immediate airway obstruction and rapid death. Because helmets significantly reduce these destructive force vectors, evaluating headgear status and chin strap security should be standard practice in every forensic road traffic autopsy.

DECLARATIONS

Ethical Committee Approval

The study protocol was formally approved by the Institutional Ethics Committee and Research Review Board of S.M.S. Medical College and Attached Hospitals, Jaipur.

Acknowledgements

The authors thank the mortuary and technical staff of the Department of Forensic Medicine & Toxicology at SMS Medical College, Jaipur, for their continuous support during post-mortem data collection.

Source of Funding

Self-Generated

Conflict of Interest

None to declare

Availability of Data and Materials

The data generated and/or analyzed during the present study are available from the corresponding author on reasonable request.

Competing Interests

The author declares that there are no competing interests.

Authors' Contributions

The author conceived and designed the study, performed the surgical procedures, contributed to data collection and interpretation, and prepared and approved the final manuscript.

AI Use Disclosure

The authors declare that no generative artificial intelligence tools were used to generate or substantially modify the scientific content of this manuscript.

REFERENCES

1. **Boffano P, Kommers SC, Karagozoglu KH, Forouzanfar T.** Aetiology of maxillofacial fractures: a review of published studies during the last 30 years. *Br J Oral Maxillofac Surg.* 2014 Dec;52(10):901-906. DOI: 10.1016/j.bjoms.2014.08.011.
2. **Gassner R, Tuli T, Hächl O, Rudisch A, Ulmer H.** Cranio-maxillofacial trauma: a 10-year review of 9543 cases with 21067 injuries. *J Craniomaxillofac Surg.* 2003 Feb;31(1):51-61. DOI: 10.1016/s1010-5182(02)00168-x.
3. **Abhinav RP, Selvarasu K, Maheswari GU, Taltia AA.** The patterns and etiology of maxillofacial trauma in South India. *Ann Maxillofac Surg.* 2019 Jan-Jun;9(1):114-117. DOI: 10.4103/ams.ams_233_18.
4. **Rupani R, Singh M, Kumar V, Singh R, Kumar S, Yadav P.** The maxillofacial injuries: a postmortem study. *Natl J Maxillofac Surg.* 2018 Jan-Jun;9(1):48-51. DOI: 10.4103/njms.NJMS_31_17.
5. **Yadollahi M, Arfaatabar M, Paydar S, Niakan MH, Ghiasi HR, Niakan AN, et al.** Pattern of maxillofacial injuries and determinants of outcome in a large series of patients admitted to a Level-I trauma center. *Bull Emerg Trauma.* 2019 Oct;7(4):400-408. DOI: 10.29252/beat-070409.
6. **Khan TU, Khan MA, Ahmad M, Khitab U, Khan MT, Jan A.** Etiology and pattern of maxillofacial trauma presenting to a tertiary care hospital. *J Ayub Med Coll Abbottabad.* 2022 Jan-Mar;34(1):52-57. DOI: 10.55519/JAMC-01-9273.
7. **Kalathil LSM, Mangalath U, Roshni A, Aslam S, Thomas T, Nair RB.** Study of patterns of maxillofacial injuries: an institution-based observational study. *J Pharm Bioallied Sci.* 2021 Jul;13(Suppl2):S1019-S1023. DOI: 10.4103/jpbs.JPBS_310_21.
8. **Dalal D, Saha S, Sinha PK, Ejaz A, Bhaduri M, Basu P, Haldar S.** Study of the pattern of craniofacial injuries in victims of fatal road traffic accident cases autopsied in Midnapore Medical College. *Indian J Forensic Med Toxicol.* 2024 Oct-Dec;18(4):48-54. DOI: 10.37506/ijfmt.v18i4.19842.
9. **Kumar A, Tandon S, Sharma GASK, Yadav A.** Study of facial injuries sustained in cases of fatal accidents and intentional violence. *J Indian Acad Forensic Med.* 2020 Apr-Jun;42(2):114-119. DOI: 10.5958/0971-0973.2020.00028.9.
10. **Srivastava U, Haobijam N, Palin K.** Patterns, aetiology and associated complications of maxillofacial fractures at a tertiary care centre: a cross-sectional observational study. *Int Surg J.* 2025 Sep;12(9):1502-1507. DOI: 10.18203/2349-2902.isj20253811.
11. **Saukko P, Knight B.** *Knight's Forensic Pathology.* 4th ed. Boca Raton: CRC Press; 2016. DOI: 10.1201/b13266.
12. **Payne-James J, Byard RW, Corey TS, Henderson C.** *Simpson's Forensic Medicine.* 14th ed. Boca Raton: CRC Press; 2019. DOI: 10.1201/9781315155517.