D18 Mechanisms of Motorcycle Helmet Accident Retention Failures and Experimental Comparisons With a Safer Alternative Retention System Design Used in an Adult Football Helmet

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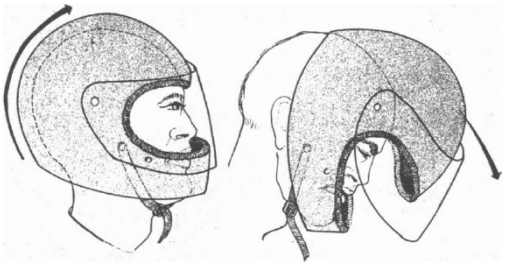
Learning Overview: This presentation presents methods for forensic analysis of motorcycle helmet detachment mechanisms during crashes and demonstrates an anthropomorphic head-impact test for comparison of defective retention systems with available alternative safer helmet designs.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by showing how and why helmets are displaced or ejected in collisions and alternative design retention systems that attenuate or eliminate loss of helmet performance and head protection.

Helmet protective capacity is diminished or non-existent if displaced or ejected. Helmet research on displacement/detachment during crashes was published by Richards and Hurt, et al.[1,2] The United Kingdom Department for Transport reported "helmet detachment … in 10% to 14% of casualties."[3] Restrained helmets can be significantly displaced or ejected off the head in motorcycle impacts, due to "loose fastening of the chin strap and possibly a loose-fitting helmet."[3] Hurt noted "helmets properly fitted, retention system securely fastened, but the helmet is ejected."[2] Richards diagrammed how properly fitted and securely fastened helmets can eject in frontal impacts where "the torso is slowed … but forward inertia of the helmet, the geometric attachment of the chin strap system, plus head rotation, allows the helmet to roll off the head before impact with another vehicle, and/or other fixed objects."[1]



Manner in which helmet is detached at high speed, showing (left) normal position and (right) helmet pivoting forward on strap during accident.

Another mechanism occurs if "head impact crushes front helmet padding, forward movement within the helmet causes a gap between the occiput and rear padding, loosening the helmet the same as if poorly fitted.[1] Additional severe head impacts, with the helmet misaligned or completely detached from the head, can occur. "Double D-ring" single chinstrap designs in use since the 1950s, (above,) cinch the helmet downward onto the top of the head, but the helmet is still free to rotate forward. "Full-face" helmets create additional fulcrum effects, increasing helmet rotation about the chin strap attachments. This was demonstrated by tests on open-face and full-face helmets securely attached to the head and neck of fifty percentile male Hybrid-III surrogates using a pendulum impact testing shown in a prior AAFS paper.[1] Video clips below demonstrate "roll-off" of a full-face helmet system 45msec after a 6.9m/s impact. (Note occipital area displaced from helmet.) This resulted in a 170J impact energy applied to the helmet frontal region. Resultant head acceleration was 296G and 15msec HIC was 732. The maximum pitch angular velocity was 31.5r/s.

A remedy for single chin strap defects was noted in identical testing of a football helmet retention design where a "two-strap" retention system was attached in a "Y"-shape manner, with one strap oriented from a "chin-cup" over the head apex (similar to the "Double D-ring" schematic) and another strap, oriented to the rear interior of the helmet so padding is pulled tightly beneath the occipital condyles, eliminating helmet rotation off the head.[4]

Football helmets with face masks have a similar geometry to full-face motorcycle helmets. Impact to these face protection structures can have similar "fulcrum" effects on the helmet, causing displacement or ejection from the head. The figure below shows that this "Y" retention system design holds the football helmet securely to the head. Peak resultant acceleration was 219G and 15msec HIC was 518. Better-secured helmet mass provided reduced head pitch angular velocity of 26.1r/s, and a lower likelihood of rotationally induced head injury, versus higher 31.5r/s pitch rate of the motorcycle helmet.

Piozzi conducted tests using Hybrid III head/necks comparing motorcycle helmet single straps with "Y"-type straps from "shorty"-type motorcycle helmets and "Y"-type bicycle helmet straps. Significant improvements in helmet stability and retention were shown by "Y"-type straps.[5] Existing helmet Standards FMVSS 218, British Standard 6658, and ECE Standard 22.05 do not adequately evaluate these helmet retention deficiencies or head injury risks.

In summary, dynamic testing of helmet retention systems via this human responding head-neck and pendulum impact test method provides accurate head injury risk assessment of alternative safer retention systems. This enables proper forensic evaluation of helmet system retention performance and related causes of head injury, regardless of compliance with limited government safety standards.

Reference(s):

1. Saczalski, K.J. et al. Motorcycle Helmet Translational & Rotational Head Injury Risk Measures Using H-III Head Impact Tests. *Proceedings of the American Academy of Forensic Sciences*, 67th Annual Scientific Meeting, Orlando, FL. 2015. D3.
2. Hurt, H.H., Jr., Thom, D.R., Ouelllet, J.V. Testing for Positional Stability of Motorcycle Helmets. *Proceedings of the International Technical Conference on Enhanced Safety of Vehicles (ESV)*, Paper Number 98-510-P-30, Windsor, Canada 1998.
3. http://sharp.DfT.gov.uk/sharp-testing/.
4. Xenith X2E+ large size adult football helmet purchased in 2018.
5. Personal communication, 1996.

Motorcycle Helmet Retention, Football Helmet Retention, Head Injury Severity