A STUDY OF 93 FATAL TWO-WHEELED MOTOR VEHICLE ACCIDENTS

by

J.B. Pedder, S.B. Hagues, G.M. Mackay

Accident Research Unit, Department of Transportation and Environmental Planning, University of Birmingham, Birmingham, England.

Introduction

This paper describes a sample of 93 accidents involving 96 fatally injured two-wheeled motor vehicle* users. 92 of these fatal riders† were known to be wearing a crash helmet at the time of the accident. Although medical information is collected for all casualties, only the injuries sustained by the fatal riders are described in this paper.

The accidents were investigated as part of an ongoing study. The sample represents 65% of all fatal TWMV accidents that have occurred in our study area since the project began in 1977.

The accidents are typically followed up within 7 days of their occurrence, the involved vehicles inspected and the accident scene visited. Further data is collected from police files and when available, the crash helmet is examined. A copy of the post mortem report is obtained and additional medical information is collected from interim medical services used.

In order to establish that there was no apparent selection bias we compared our sample with the latest published accident figures for Great Britain. These were for 1977, when 1,182 TWMV users died as a result of road traffic accidents. (ref 1). In national statistics, a road accident is defined as fatal if death occurs within 30 days of the accident. There was only one user in our sample who died outside this period.

So, the 93 accidents investigated were compared with national figures by accident environment, age and sex of rider, and whether the rider was a driver or passenger. There was no difference between the two groups in the distribution of these variables at the 5% level of confidence.

*The abbreviation "TWMV" will henceforth be used for "two-wheeled motor vehicle".

†The term 'rider' refers to both the driver and the passenger of the TWMV.

The Sample

58 accidents occurred in urban areas, defined by a speed limit not greater than 40 mph. The road surface was reported dry for 58 accidents and wet on 29 occasions. There were 47 accidents during daylight hours. Street lamps were present and lit in 33 of the 43 accidents which occurred at night. A full breakdown of these features is given in Table 1.

Table 1 : Sample and National Distributions of Accident Environment

	Sample Distribution		National Distribution (ref 2)	
Area Type	N	%	N	%
Urban areas (speed limit ≤ 40 mph)	58	(62)	670	(59)
Rural areas (speed limit > 40 mph)	33	(35)	460	(41)
Not known	2	(2)	1	(0)
Road Surface				
Dry	58	(62)	794	(70)
Wet	29	(31)	327	(29)
Snow and/or ice	3	(3)	10	(0)
Not known	3	(3)		
Street Lighting				
Daylight	47	(51)	610	(54)
Street lamps, all lit	33	(35)	362	(32)
Street lamps, part-lit	3	(3)		
Street lamps, unlit	1	(1)	6	(0)
No street lamps	6	(6)	152	(13)
Not known	3	(3)	1	(0)

The type of TWMV available to the users is partially controlled by legislation. In Great Britain riders who do not hold a full TWMV licence are not allowed to ride a machine above 250c.c., and since 1972, 16 year olds have been restricted to mopeds*. There were 13 mopeds in our sample, and one 200 c.c. motor-scooter. The engine size breakdown for the motorcycles is given in Table 2.

*In August 1977 the moped was redefined from a TWMV 'not over 50 c.c. equipped with pedals' to a TWMV 'not over 50 c.c. with a maximum design speed of 30 mph and a kerb weight not exceeding 250 kg'.

Table 2 : Engine Size of Motorcycles in Cubic Centimeters (c.c.)

≤ 100 c.c.	5
100 - 250 c.c.	49
251 - 500 c.c.	7
≥ 500 c.c.	18

As far as the authors are aware there is no national data currently available on TWMV usage rates by engine size.

The Accident

A. There were 35 single vehicle accidents. In 15 of these cases, the driver dropped his machine in the road. On another 17 occasions the upright TWMV, with the user(s) still astride hit the kerb before complete loss of control occurred. In 3 accidents, loss of control resulted from collision with a pedestrian. In 2 of these cases, the pedestrian was also killed.

24 fatally injured riders in this accident group hit off-road objects. At the time of this impact 12 riders were still on their TWMV, 7 riders were no longer with their vehicle, and it was not ascertained for 5 riders.

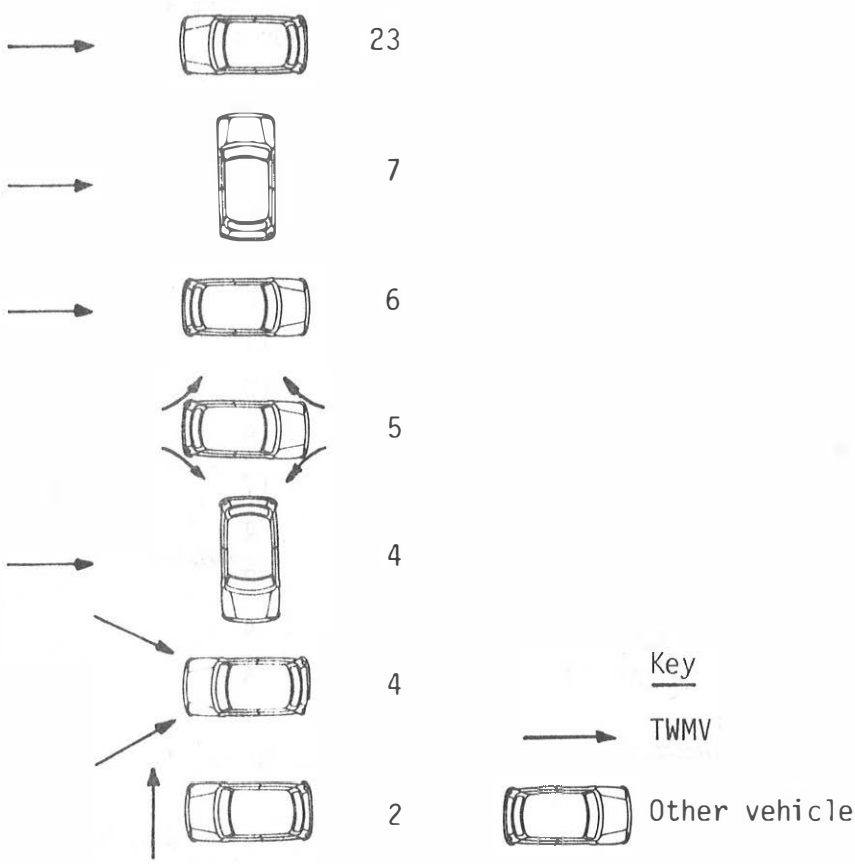
B. There were 58 multi-vehicle accidents. In 52 cases only 1 other vehicle was involved, this includes 7 accidents where it only struck the TWMV rider. 5 accidents involved 2 other vehicles, and in 1 accident there were 3 other vehicles. Table 3 shows the type of the first other vehicle hit by the TWMV.

Table 3 : Type of First Other Vehicle Hit by TWMV

Car or car derivative	31
Heavy goods vehicle	8
Light van	5
TWMV	3
Public service vehicle	2
Pedal cycle	2

Among this group of 51 accidents there were 23 head-on collisions, 10 accidents where the TWMV went into the side of the other vehicle and 6 where it hit the rear of another vehicle. The accident configuration is given in Table 4.

Table 4 : Point of Impact for the TWMV with the 1st Other Vehicle



This means that 41% of our fatal accident sample approximate to the experimental motorcycle collision tests between an upright TWMV and another vehicle. This illustrates the relevance of such crash tests.

Only 5 riders involved in multi-vehicle accidents subsequently hit off-road objects.

The Fatally Injured Riders

In the 93 accidents, 88 drivers and 8 passengers were killed. The driver was the sole occupant in 77 cases, and in 3 accidents both the driver and passenger died. Table 5 gives the fatal user's position on the TWMV.

Table 5 : Fatal User Position on TWMV

	No. of accidents
Driver killed, sole occupant	77
Driver and passenger killed	3 (= 6 fatal users)
Driver killed (with non-fatal passenger)	8
Passenger killed (with non-fatal driver)	5

There were 91 males and 5 females. The females were all passengers. The age distribution for the fatal casualties is shown in table 6, 69 (72%) were aged between 16-20 years. As far as the authors are aware no data are available on TWMV usage rates by age or rider.

Table 6 : Usage Rates by Age of Rider

Rider's age (in years)	No. of Drivers	%	No. of Passengers	%
16	12	14		
17	19	22	2	25
18	11	13	3	38
19	10	11	2	25
20	9	10	1	13
21 - 25	13	15		
26 - 30	4	5		
31 - 35	2	2		
36 - 40	4	5		
over 40	4	5		
Total	88		8	

All provisional licence holders, drivers who have not passed the Dept. of Transport TWMV riding test, must display 'L' plates on their vehicle. 35 of the accident vehicles carried 'L' plates. The period of TWMV road riding experience was known for 43 riders, 14 had less than six months experience, 26 had been riding for more than one year.

Blood alcohol levels were known for 42 accidents. These were cases where death occurred within roughly 12 hours, no transfusions were performed and specimens were available for sampling. Therefore there is good reason to believe that the blood alcohol levels are typical of the whole sample. In 52% of these cases the driver's blood alcohol level was greater than 80mg/100ml. Since 1967 it has been an offence to drive in Great Britain with over 80mg of alcohol per 100ml of blood. The breakdown of blood alcohol level is shown in Table 7.

Table 7 : Driver's Blood Alcohol Level (mg/100ml)

0 mg	18
1 - 80 mg	2
81 - 150 mg	11
151 - 200 mg	8
> 200 mg	3

Patterns of Injury

A. Post mortem report

In Great Britain, post mortems are performed on all fatal road accident casualties to establish the cause of death. Although there is a standard autopsy procedure, the reporting of post mortem findings varies considerably. It is important to note the limitations of these reports, as on 73 occasions where death was instantaneous the pathologists report was the sole source of injury information.

The main interest of the pathologist is to establish the cause of death for the coroner, so in some cases only the severe and fatal injuries are reported. In view of the severe nature of the injuries it seems likely that surface injuries are unreported rather than absent. Further, the cervical spine and extremities are only examined externally, and fractures, especially in the limbs, are rarely dissected out.

B. Injuries

The outstanding feature of the injuries received by this sample of TWMV users is both the multiplicity and the extremely severe nature of the injuries. The injuries sustained by each body area were assessed using the Abbreviated Injury Scale, A.I.S. (ref 3). The multiplicity of the injury and the high incidence of severe head, chest, and abdomen injuries is seen in Table 8.

Table 8 : Highest AIS for Given Body Areas

AIS	Head	Neck	Chest*	Abdomen	Arms	Legs
0	18	58	23	38	30	18
1	2	12	3	6	17	13
2	0	7	4	3	35	46
3	0	4	20	9	8	7
4	6	3	4	4	6	12
5	58	3	35	35		
6	12	9	7	1		

*Including thoracic spine.

Table 9 shows the Injury Severity Score, I.S.S. (ref 4) which was calculated for each casualty.

Table 9 : Injury Severity Score

I.S.S.	No. of Cases	I.S.S.	No. of Cases
04	1	38	11
21	1	42	3
24	1	43	5
26	3	45	2
27	2	50	5
29	4	54	6
30	3	59	9
33	6	66	16
34	1	75	17

Table 10 shows the body area(s) with the highest or equally highest AIS scores for each casualty.

Table 10 : Body Area(s) with Highest or Equally Highest AIS

	AIS					
	2	3	4	5	6	ALL
Head				30	8	38
Neck			1	1	5	7
Chest			1	6	5	12
Abdomen				2		2
Lower limbs	1		1			2
Head and neck					2	2
Head and chest				9		9
Head and abdomen				7		7
Neck and abdomen				1		1
Chest and abdomen				6		6
Head, neck and chest					1	1
Head, chest and abdomen				7		7
Neck, chest and abdomen				1		1
Head, neck, chest and abdomen					1	1

In view of the severity of the injuries sustained it is not surprising that 73 riders were certified dead at the scene or on arrival at a hospital. A further 5 died on the day of the accident. The time to death for the entire sample is given in table 11.

Table 11 : Time to Death

Instantaneous	73
< 6 hours	4
6 - 12 hours	1
12 - 24 hours	0
1 - 3 days	4
3 - 7 days	5
1 week - 1 month	8
> 1 month	1

Table 12 gives details of the locations and severity of injuries in the main body area.

Table 12 : Location and Severity of Injuries for Named Body Areas

	AIS	1	2	3	4	5	6
Head	Surface	19	9				
	Skeletal		2		49	2	4
	Internal				5	58	12
Face	Surface	21	34	2			
	Skeletal	3	11	7			
	Internal	5	2	1	2		
Neck	Surface	14	8		1		1
	Skeletal			4		3	9
	Internal	2			3	1	9
Arm	Surface	26	34				
	Skeletal		11	8	6		
	Internal		1				
Legs	Surface	20	50				
	Skeletal		8	5	14		
	Internal		5	1			
Chest	Surface	12	14				
	Skeletal	1	8(3)*	26	4(2)*		1
	Internal	1		18	4	34	7
Abdomen	Surface	7	6	1			
	Skeletal				1		
	Internal				4	35	1

*Numbers in bracket refer to thoracic spine injuries.

Head Injuries

There was a high incidence of basal skull fractures with 35 out of the 57 casualties who received a skull fracture of some description, suffering fractures in the base.

Brain damage rated as AIS 4, 5, or 6 was reported for 75 casualties. In 20 (27%)of these cases the brain injuries occurred without any skull fracture. Of the remaining 55 cases, 13 involved brain injury with an overlying fracture and 12 were reported as exhibiting brain injury associated with a fracture in the base of the skull. 30 cases were not reported in sufficient detail to allow these distinctions to be made.

Neck Injuries

9 casualties sustained an injury to the cervical spine in the region of the first 3 vertebrae. In 6 cases injury probably occurred as a result of a direct blow to the user's head.

Source of Injury.

The source of injury is not readily ascertained in this type of road user. The paucity of surface injury data precludes the possibility of identifying rider contact from the type of abrasion. So, in most accident situations it was not possible to isolate a particular contact as causing a surface injury. The source of surface injuries have mainly been recorded as not known. Table 13 shows the source of injuries for the main body areas. In some cases this includes a subsequent rider contact which has been identified as a second source of injury.

In many accidents, there was an identifiable contact between the TWMV rider and another vehicle, or an off-road object. However, it is important to note that such contacts may be masking the possible importance of prior or subsequent ground contacts as a source of injury. The possible involvement of the casualties own vehicle as a source of abdominal injuries should not be discounted. At this stage of the research, it is difficult to ascertain the importance of the TWMV as a source of injury.

Table 13 : Source of Injury for Given Body Areas

	Head		Face		Neck	
	1st	2nd	1st	2nd	1st	2nd
Own TWMV	0		1		0	
Other vehicle	20	1	14(1)*		5(1)*	
Off-road objects	18(1)*		10(1)*		7(4)*	
Ground (road etc)	12	8	6(1)*	3	2(1)*	
Kerb	4		1		0	
Runover	4		3		1	
Helmet &/or visor	0		3	1	1	
Not known	19	3	1		16	

Table 13 Continued

	Chest		Abdomen		Arms		Legs	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Own TWMV	0	1	2	2	1	1	4	2
Other vehicle	27		16		11	1	14	1
Off-road objects	20		12	9	6		3	
Ground (road etc.)	10(1)*	2	5		20	3	14	6
Kerb	0		0		0		0	
Runover	1		2		1		1	
Not known	14	4	21		27		42	

*Numbers in brackets refers to those injuries which were indirectly induced by the named contacts.

The Helmets

Since 1973 it has been compulsory for all TWMV users to wear a crash helmet. The helmet must either comply with British Standards or be of a type expected to give at least a similar degree of protection.

There are 2 current British Standards for crash helmets - B.S. 2495/77 is the 1977 revision of B.S. 2495/60, and B.S. 5361/76 replaces B.S. 2001 and B.S. 1869. The retention systems test is the same for both current standards (ref 4). The British Standard shown on approved labels attached tothe accident helmets is given in Table 14.

Table 14 : British Standard Specification Shown on Rider's Crash Helmets

B.S. 2001	8
B.S. 1869	11
B.S. 5361/76	18
B.S. 2495/60	17
B.S. 2495/77	1
B.S. label, but number not known	14
Not known	23

92 users were known to be wearing a crash helmet at the time of the accident, no information was available for the remaining 4 people. 58 of the helmets were fully examined by the research team and a further 11 were examined superficially. Brief details only were noted on the remaining 23 cases.

There were 49 'full face' helmets, 26 'jet/open face' style helmets and 2 helmets were 'pudding basin' style. Information was not available for the other helmets.

33 helmets in the sample came off at some stage in the impact sequence. Head injuries above AIS 3 were sustained by 79% of the casualties who lost their helmets. Examination of the helmet shells and liners indicated that 12 (36%) of these helmets came off without sustaining a major direct impact. A further 11 of the helmets showed evidence of being in position for at least one major direct impact and insufficient information was available on the remaining 10 helmets to allow a decision to be made. There must always be some doubt about how the helmet was fastened prior to impact in such accidents, but in 15 of these cases, there was definite evidence of mechanical overload being applied to the chinstrap or its fastenings. Two examples of such overloads are shown in photos 1 and 2.

It is of note that in no case in the present study was any life threatening injury attributed to loading produced by the chin strap.

The research in this paper is continuing and further and more detailed analyses of all areas covered in the present paper will be presented in due course.

Conclusions

For this sample of 96 TWMV fatalities:-

1) The distributions of age, sex, rider position, and accident environment are not significantly different at the 5% level of confidence from national data.

2) 38% of the fatal accidents involved no other vehicle, thus 62% involved a collision with at least 1 other vehicle and in the majority of those cases there was an impact between at least one of the riders and the other vehicle.

3) 30% of the fatalities struck off-road objects (including street furniture).

4) A crash test with a rider on an upright TWMV impacting another vehicle approximates to 41% of the impacts in the present study.

5) 95% of the casualties were males and 72% of the fatalities were between the ages of 16 and 20 years (inclusive).

6) The driver's blood alcohol level was above 80mg/100ml of blood in at least 22 of the 93 accidents, i.e. in 52% of the cases where a B.A.L. figure was available.

7) In 68% of the fatalities the head sustained the highest or highest equal AIS. The highest or equal highest AIS occurred in the chest in 26% of the cases.

8) 76% of the casualties were either certified dead at the scene or directly on arrival at the hospital.

9) For those sustaining skull fractures 61% suffered fractures of the base.

10) 27% of those sustaining life threatening brain injuries did not have a skull fracture.

11) 36% of helmets came off the rider's head at some stage in the accidents. Of these, at least 12 (36%) came off without apparently sustaining major direct impact.

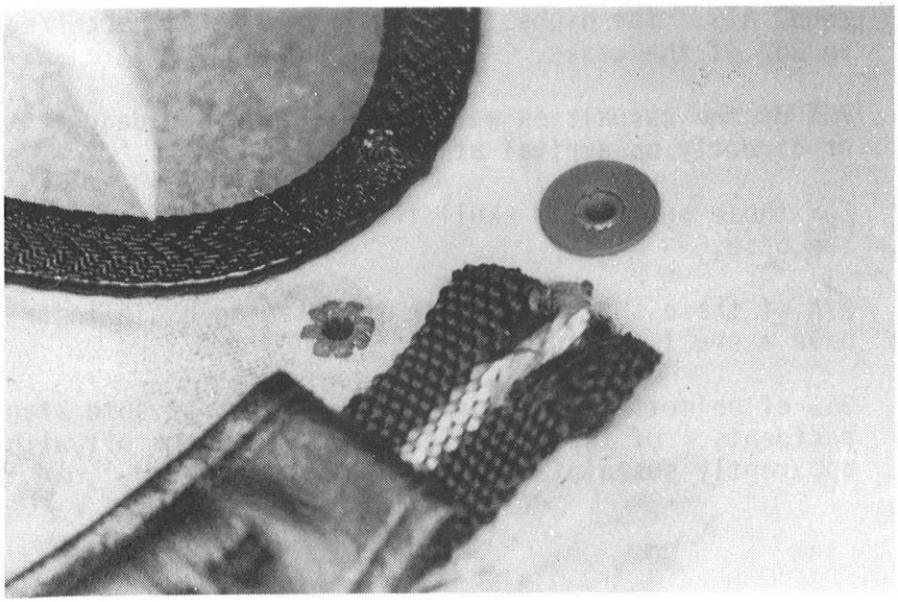


Photo. 1a. Chin strap end which has parted from rivet attachment to helmet shell during accident. Helmet carries a B.S. 5361 label

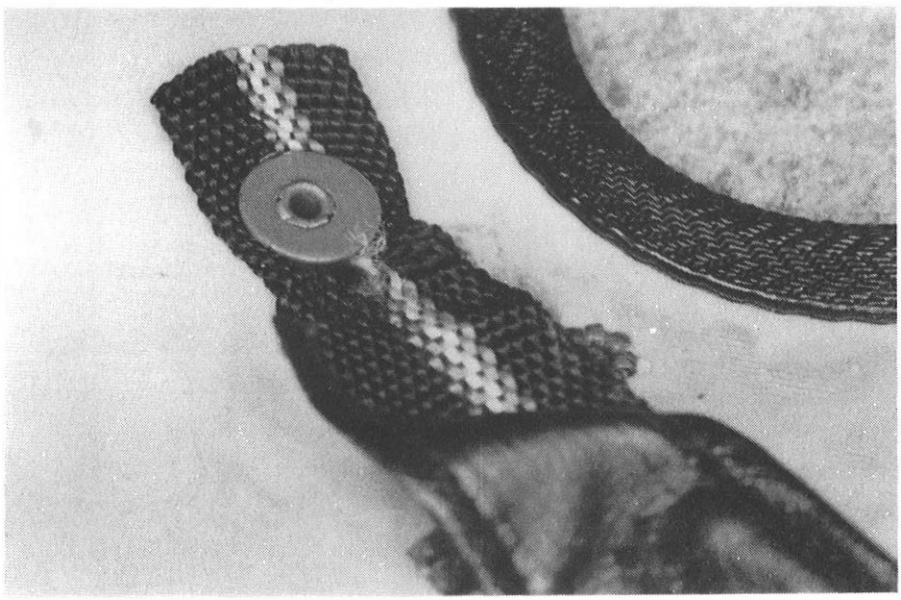


Photo. 1b. Chin strap end on opposite side of same helmet. Note webbing damage by rivet.

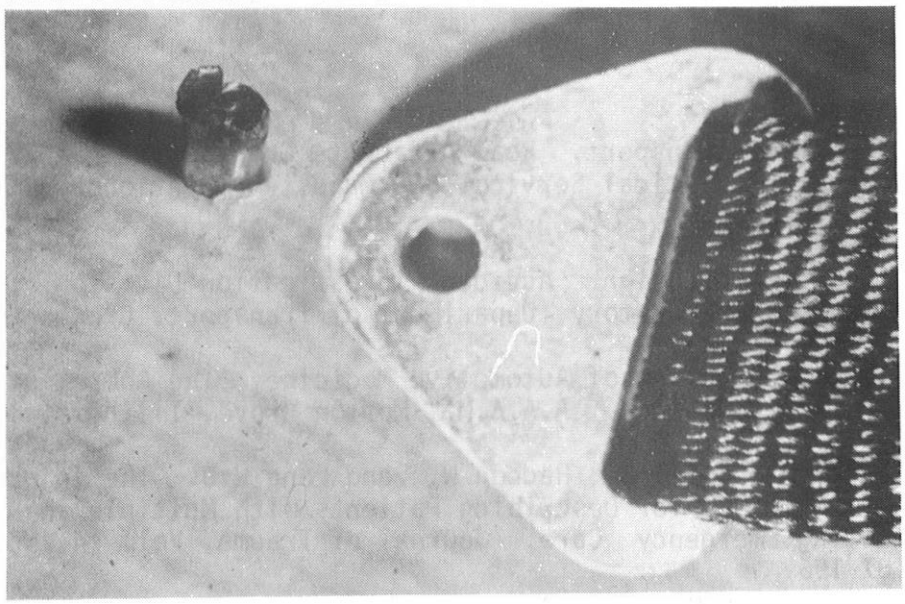


Photo. 2a. Triangular metal plate on end of chin strap has parted from rivet attachment to helmet shell during accident. Helmet carries a B.S. 1869 label.

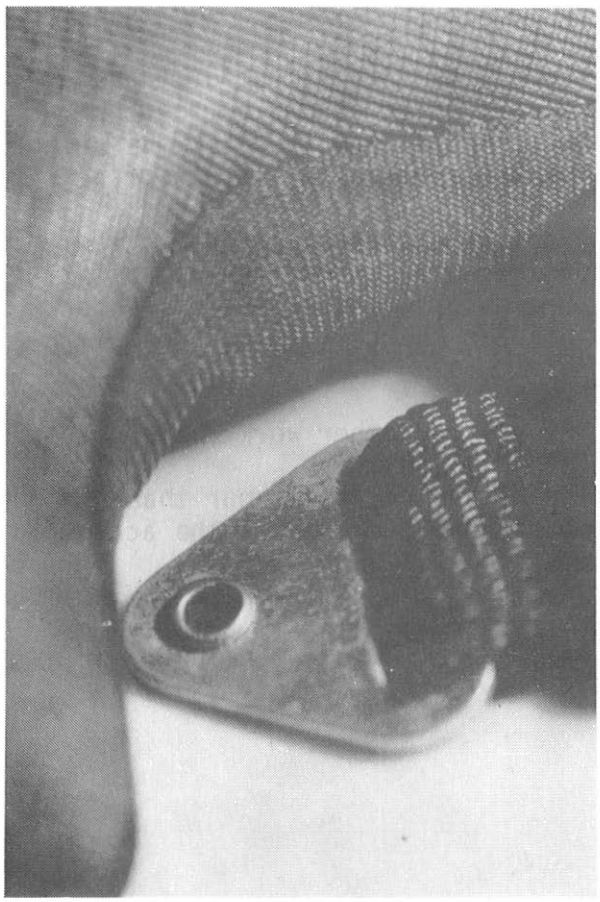


Photo. 2b. Opposite side of same helmet with the metal plate still in position.

References

1. Department of Transport. Road Accidents Great Britain 1977. Government Statistical Service, Her Majesty's Stationery Office, London, 1978.

2. Personal communication. Accident Investigation Division, Transport and Road Research Laboratory, Department of Transport, Crowthorne, England.

3. American Association of Automotive Medicine. The Abbreviated Injury Scale (1976 Revision). A.A.A.M., Morton Grove, Illinois, 1976.

4. Baker S.P., O'Neill B., Haddon W., and Long W.B. The Injury Severity Score : A Method for Describing Patients with Multiple Injuries and Evaluating Emergency Care. Journal of Trauma, Vol. 14, No. 3, P. 187-196.

5. British Standard Institution. Specifications for Protective Helmets - BS 1869 : 1960, BS 2495 : 1960, BS 2001 : 1972, BS 5361 : 1976, BS 2495 : 1977. London, England.

Acknowledgements

This research is financed by the Department of Transport, the authors appreciate the support and interest shown by the contract supervisors. The views expressed in this paper are those of the authors and do not represent the views of the Department of Transport.

Our thanks to the many police officers, coroners, medical and forensic personnel for their considerable and continuing assistance. We are grateful to Dr. Bull, Professor Gissane and Miss Roberts of Birmingham Accident Hospital for help in the collection and interpretation of medical data.

Special thanks to Dr. Gloyns and other work colleagues for all their help.

Finally, to the families of the deceased, our thanks for allowing us to retain the crash helmet worn at the time of the accident.