TWO WHEELERS ACCIDENTS : Injury mechanisms and means of prevention.

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INTRODUCTION :

From I976 to I980, the O.N.S.E.R laboratory conducted three accident investigations concerning two wheelers.

- The first one analysed the data of I50 moped users involved in traffic accidents.
- The second one concerned I50 of motor cyclist victims
- The third one is focused on the behaviour of new helmets and takes into account I00 of two wheelers wearing an helmet and injured in traffic accidents.

In this paper are joined the results of these three studies.

The sample can be divided in two parts :

-223 motor cyclists with 22I of them helmeted

-177 moped users with 77 of them helmeted

The number of fatally injured people is 27 motor cyclists (I2,1% of them) and 7 moped users (3,9% of them).

All the victims of this investigation are injured and were treated at the E. HERRIOT Hospital in Lyon.

I - SEVERITY OF INJURIES

I-I Overall severity of victims :

Figure 1 summarizes the distribution of OAIS values for moped users and motor cyclists.

This figure shows the high severity of motor cyclist accidents. The frequency of AIS 3 and more, is always higher for motor cyclists than for moped users.

FIG 1 - OAIS DISTRIBUTION

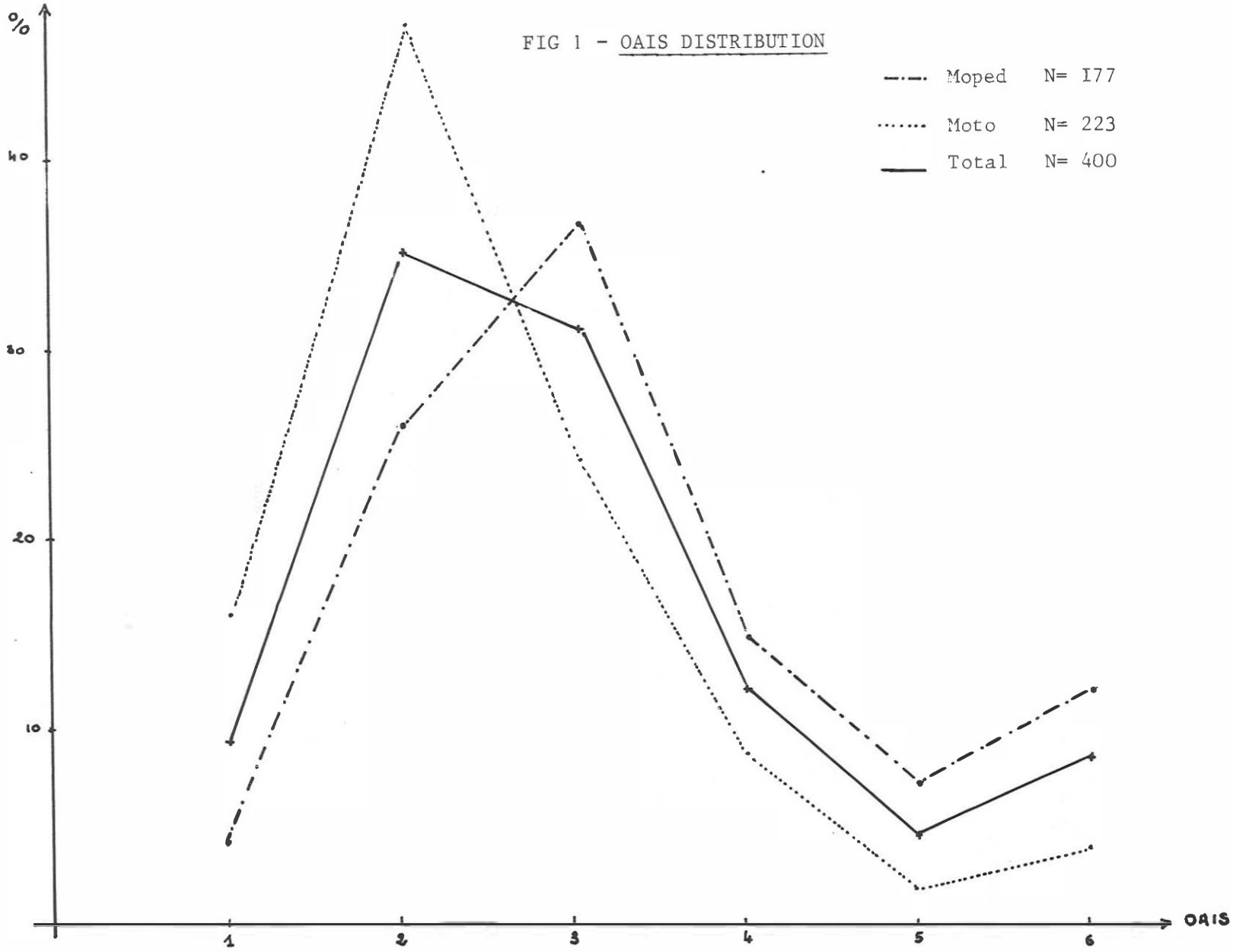
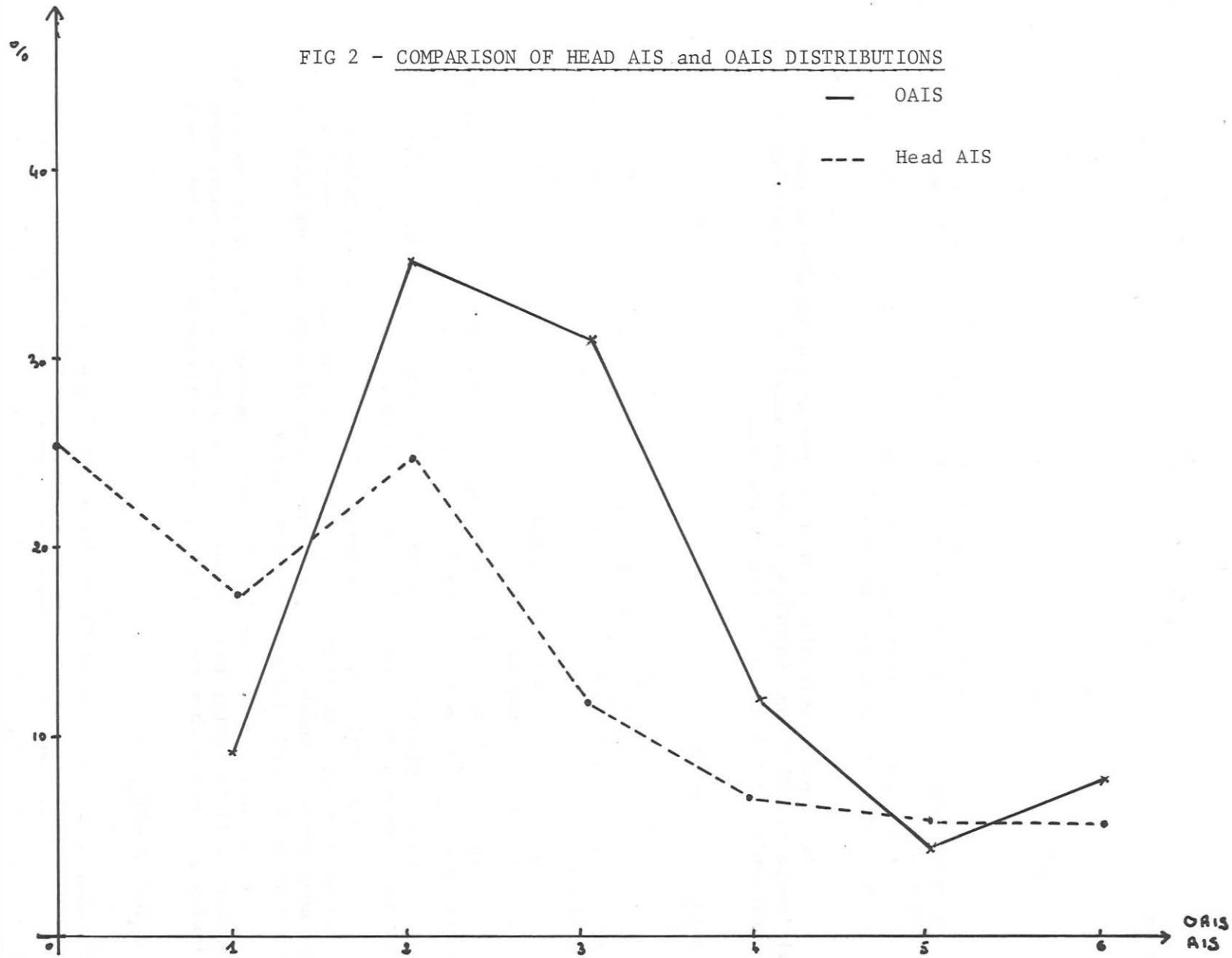


FIG 2 - COMPARISON OF HEAD AIS and OAIS DISTRIBUTIONS



The most important difference is found for fatally injured people : the mortality rate is three times higher for motor cyclists than for moped users.

I-2 Severity of head injuries :

Comparison of head AIS and OAIS distributions is made on Figure 2. This diagram shows that a quarter of the 400 injured people does not sustain head injury.

For the most severe injuries, (AIS 5 and 6), the two distribution curves are closed, which means that overall injury severity is due to head injury.

It is noticeable also that a quarter of the victims in this sample sustains AIS 2 head injuries, which are mainly head trauma with short unconsciousness($\leqslant$15mn) and/or retrograd amnesia.

I-3 Injury typology :

Figure 3 shows anatomical distribution of injuries.
It shows that head injuries are as frequent in motor cyclist cases than in moped cases.

Differences appear in thoracic and abdominal lesions which are more frequent in the motor cyclist 's sample.

The pelvic girdle and lower limbs are also more often injured, and we notice a high frequency of thoracic and lumbar spine lesions.

On the opposite, neck injuries are much more frequent in the moped users sample than in the motor cyclist's one.

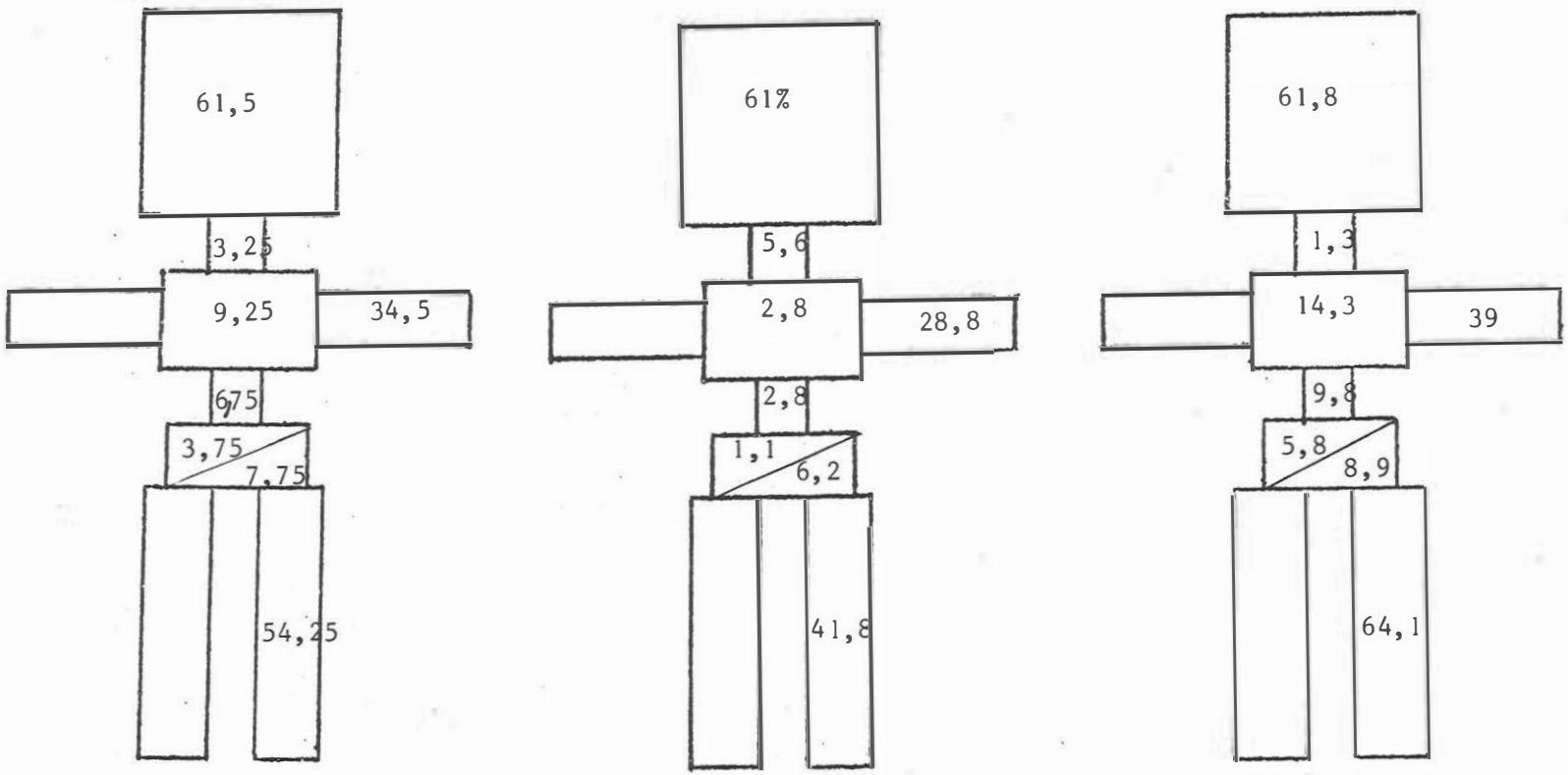
In a general way, we can notice that the frequency of injuries per body area is more important for each body area for the motor cyclists, except head injuries which are in the same order of magnitude and neck injuries which are more frequent on moped users.

Moreover, if we consider the average number of injuries, we remark that motor cyclists suffer two lesions on an average, and moped users only 1.5 lesion ; it means that motor cyclists sustain frequently a polytrauma.

II - INJURY MECHANISMS

2-1 Motor car aggressivity facing the two wheelers users.

Before studying the motor car aggressivity facing the two wheelers, we notice that the cars are the most frequently obstacle hit by the two-wheelers ; it is shown in table 1.



Total 400

Moped users (177)

Motor cycle users (223)

FIG 3 - ANATOMICAL DISTRIBUTION OF INJURIES

Table 1 : Obstacles hit by the two wheelers, at the first impact.

Cars	:	59,75%
Trucks	:	9,75%
Vans	:	4,5 %
Fixed obstacles	:	7 %
Ground	:	16 %
Pedestrian	:	1,25%
Two wheelers	:	1,75%

The collisions happen generally at road intersections and in agglomerations.
In these collisions, the front end of the car is the most frequently collided by the two wheelers (35%).

- Injury mechanisms concerning the lower body part :

All the body segments of the two wheeler users can be concerned, but the inferior part of the body, particularly the lower limbs, is often injured. Indeed, 169 lesions AIS $\geq$ 2 are noticed at lower limbs.

Table 2 : Moped users sample : lowers limbs and pelvic injuries mechanisms :

	Direct Impact Force	Transmitted Impact Force
Pelvis	2	5
Acetabulum		3
Femur	9	2
Knee	11	
Leg	39	

For moped users, (table 2), the more frequent injury is an associated fracture of tibia and fibula, due to direct impact on the front end of the car (39 cases).
The femur fractures are less frequent (11 cases) and the injury mechanism can be considered as a direct impact of bonnet front end or optical system on the middle part of the thigh ; but sometimes, the impact force is transmitted to femur shaft from knee contact : the same mechanism is noticed in 8 cases of acetabulum fractures.

In one case, the impact force is translated along the femur shaft to the pelvic girdle, realising femur shaft, acetabulum and pelvic associated fractures.

It is interesting to notice that these moped users fractures are simple fractures without multiple fragments.

Table 3 : Motor cycle user sample : lower limbs and pelvic injury mechanisms.

	Direct Impact Force	Transmitted Impact Force
Pelvis	3	6
Acetabulum		8
Femur	16	18
Knee	29	
Leg	38	

In motor cycle user sample, (table 3), the associated fractures of tibia and fibula are less frequent, whereas femur fractures are too much current, as in moped user sample.
In 16 cases, femoral fractures are due to direct impact by the car on the thigh, and in 18 cases, the femoral fracture is created by indirect impact on the patella. The knee and the patella are often injured (29 cases), the car hitting directly this body region.

These injuries are often associated :

Knee and femur fractures	:	5 cases
Knee and acetabulum	:	5 cases
Femur and acetabulum	:	3 cases

If we notice that the thigh fractures are often simple (in two fragments only), the gravity is due to open fracture or traumatic amputation.

The table 4 shows the gravity of lower limbs and pelvic injuries in terms of AIS values.

Table 4 : Lower limbs and pelvis AIS for moped and motor cycle users.

	AIS 2	AIS 3	AIS 4
Moped users	41	26	2
Motor cycle users	36	60	4

- Head injuries related with head impact on the car

Table 5 : Head AIS origin at level of car structures

AIS	Sheet metal	Stiff metal elements	Windows and Windshield	Total
1	12	1	5	18
2	18	2	7	27
3	5	8	4	17
4	2	6	1	9
5 + 6	2	26	2	30
	30	43	19	92

The table 5 shows the head injuries gravity related to the car impacted area.

92 head injuries are due to a car impact and 46,7% of these lesions are created by hard parts of the car (windshield frame for instance). These rigid parts cause the most severe or fatal head injuries, whereas windshield and sheet metal elements create generally minor or moderate injuries (AIS 1-2).

2-2 Fixed obstacles aggressivity

Only 28 users sustain head injuries due to fixed obstacle direct impact.
If this crash configuration is rare, it is very severe in terms of AIS : 8 users are dead and severely injured (AIS 5).

In fact, rigid obstacles are frequently involved during the second impact, for example, when the 2 wheelers users hit a car and, ejected, fall on the ground and hit with the head an obstacle.

2-3 Injuries due to the two wheelers

We have difficulties to relate injuries suffered by the two wheelers users and the numerous deformations noticed on the motor cycle.

Nevertheless, in 13 cases, it is clear that the two wheelers is the cause of certain lesions suffered by the user.

In six cases, the two wheelers falls down on the user, after the primary impact.

In seven cases, mecanical parts of the motor cycle are the cause of the injuries.

- 2 thoracic crushes on the forkhead
- 5 tears or contusions due to the brake, the pedals...

III - IMPORTANCE OF CRASH CONDITIONS IN INJURY MECHANISMS :

Table 6 shows the values of OAIS and head AIS for helmeted and non helmeted two wheelers users in three crashes configurations :
direct impact, ejection and side swipe.

This table shows that half of the victims sustain direct impact with energy dissipation.

This crash configuration induces the most severe injury, either head injuries or whole body injuries : about 43% of them sustain AIS 3 or more head injuries, compared to less than 23% in other crash configurations.

If we consider the OAIS values actual figures are : 63% in direct impact and 48% in other crash configurations.

IV - HELMET PART

4-1 Helmet effectiveness

In this study concerning 400 two wheelers users, 298 wear a full face helmet or an open face helmet.

100 of them wear a "Nouvelles Normes" helmet.

Table 7 shows the influence of head AIS on OAIS for helmeted subjects, whatever is the helmet type.

	0-1-2	3/4	5/6	Total
Direct impact	30 / 22	14 / 22	3 / 3	47 / 47
Ejection	17 / 15	2 / 4	0 / 0	19 / 19
Side Swipe	26 / 24	10 / 11	0 / 1	36 / 36

Head AIS / OAIS

Head AIS and OAIS values as function as the crash configurations (non helmeted users) -

	0-1-2	3/4	5/6	Total
Direct impact	88 / 55	44 / 70	29 / 36	117 / 161
Ejection	37 / 25	7 / 18	4 / 5	48 / 48
Side swipe	68 / 40	12 / 36	9 / 13	89 / 89

Head AIS and OAIS values as function as the crash configurations (helmeted users) -

Table 7 : Comparison in AIS and OAIS for 298 helmet users.

	1	2	3	4	5-6	
Head AIS	68	76	37	23	45	249
OAIS	23	93	95	38	49	298

So 83% of the users wear a head injury.
This one may be : - a head trauma without unconsciousness (27%).

- a short loss of consciousness (30%).

For AIS 3, we notice that OAIS is largely due to other lesions, particularly to lower limbs ; the gravity of severe injured people or dead people is due to head injuries.
This preponderance of head injuries is progressively increasing from AIS 3 to AIS 5-6. This growth is in connection with the fact that successively the violence of the impact increases ; the helmet efficacity is reduced and this is connected with the tolerance limit of the head and of the human brain.

We just said that the cephalic extremity was very often requested and responsable of the importance of the gravity of the lesions, but there is an other important fact : the helmet loss.

4-2 Helmet loss.

On 400 two wheelers users, 298 were helmeted. 55 of them have lost their helmet during the impact.
We are studying now the loss of "Nouvelles Normes" helmet.

Table 8 shows that on 100 "Nouvelles Normes" wear helmets, 20 were lost during the impact.
In 8 cases, the loss of helmet is explainable but there are 12 cases (10 full face helmet and 2 open face helmet), for which the reason is unexplainable.

Table 8 : Helmet loss on 100 "Nouvelles Normes" helmets.

	Open face helmet	Full face helmet	total
Number of wear helmets	35	65	100
Number of lost helmets	6	14	20
Loss due to untied chin-strap	3	2	5
Helmet technical failure	1	2	3
Correct use	2	10	12

Table 9 : Moment of the loss of the helmet.

	Full face helmet	Open face helmet	total
Before the primary impact	4	12	16
During the principal impact	1	1	2
After the principal impact	1	1	2

The chronology of the helmet loss has evidently an important influence on the origin of head injury.
Table 9 shows that the helmet loss occurs 16 times before the main impact ; it means that the head was without any protection during the first impact.
Among these 20 losses, we notice 7 skull fractures with high AIS, and 13 injured people suffer from head lesions without fractures but with more or less long uncounsciousness. (4 AIS 4).

CONCLUSION :

After the analysis of the car aggressivity facing the two wheelers users, and the injured typology, we can consider the means of protection which have to be reinforced.

- For vehicles :

  We can envisage on cars, modifications of the front end which is the mainly touched part.

When the impact occurs, it has to be absorbed to decrease the strengh exerted on lower limbs.

Works are in project concerning pedestrian projections and would help for the security of two wheelers users.

- Two wheelers :

It would be possible, particularly on motor cycles, to place a frame avoiding the direct contact between lower limbs and vehicles or obstacles.

- For helmets :

The shells used today are satisfying but energy absorbing material could be improved by increasing thickness and energy absorbing characteristics.

Helmet loss is still a problem because it is often associated with severe or fatal head injuries.
