Comparison of Head-Neck Kinematics during Rear End Impact between Standard Hybrid III, RID Neck, Volunteers and PMTO's

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ABSTRACT

Various research studies performed at different Institutes (Geigl et al, 1994; Deutscher, 1994) have shown that current car seats are by no means optimised with respect to the protection of occupants during rear end impacts. Sled tests performed with volunteers and PMTO's (Geigl et al, 1994) have shown some weak points of selected car seats. In order to obtain more objective criteria for the safety of current and newly developed car seats (Muser et al,1994), it seems to be important to improve the quality of the measurement tools (Scott et al, 1993; Muser et al, 1994) for the assessment of the kinematics of head and cervical spine during simulated rear end impacts.

In a collaboration between Swiss, Swedish and Austrian Universities, sled tests allowing a comparison of head-neck kinematics between volunteers, PMTO's, a Hybrid III dummy equipped with a standard neck, and a Hybrid III dummy equipped with a RID-Neck (Svensson et al, 1992) have been performed. Identical test conditions have been chosen as far as possible in repeated tests to ensure a good comparability of the different tests. Two types of car seats were used at impact velocities ranging from 6 to 15 km/h. The mean sled deceleration's were varied between 3 g and 6 g.

METHODOLOGY OF EXPERIMENTS

TEST-BASE

All experiments were performed on a mini-sled with the specifications listed in Table 1.

Table 1: Mean Specification of the Test Sled

| dimensions:	11x1.5x1.0 m
net weight:	200 kg
max. load:	300 kg
power supply:	380 V
electric engine:	18 kW
frequency converter:	30 kW
max. speed:	25 km/h
max. deceleration:	up to 50 g

The sled is accelerated to the preadjusted speed by an electric engine. This engine is powered and controlled by an electronic frequency converter which allows to predefine the crashvelocity within a limit of ±0.5 km/h.

The whole sled assembly was developed in a way that it is easy to transport. The impact accelerations can be adjusted by special longitudinal friction-brake elements. These elements implement a predefined breaking force by setting a certain air-pressure on a compressed-air cylinder. Using multiple brake elements, well defined deceleration characteristics can be obtained. They can be predefined to ±3 m/s² if the total weight of the sled is known.

For the current set of experiments mean sled accelerations of 3 and 6 g were used for the PMTO and Dummy Tests. Volunteer tests were only performed at a 3 g level. Two impact velocities, 9 and 11 km/h, were chosen. All Volunteers were aware of the test procedures described above.

Figures 1 shows the deceleration characteristics for a typical test situation with an impact velocity of 9 km/h.

Sled accelerations were measured using a Kienzle UDS™ mounted on the sled (Geigl et al, 1994).
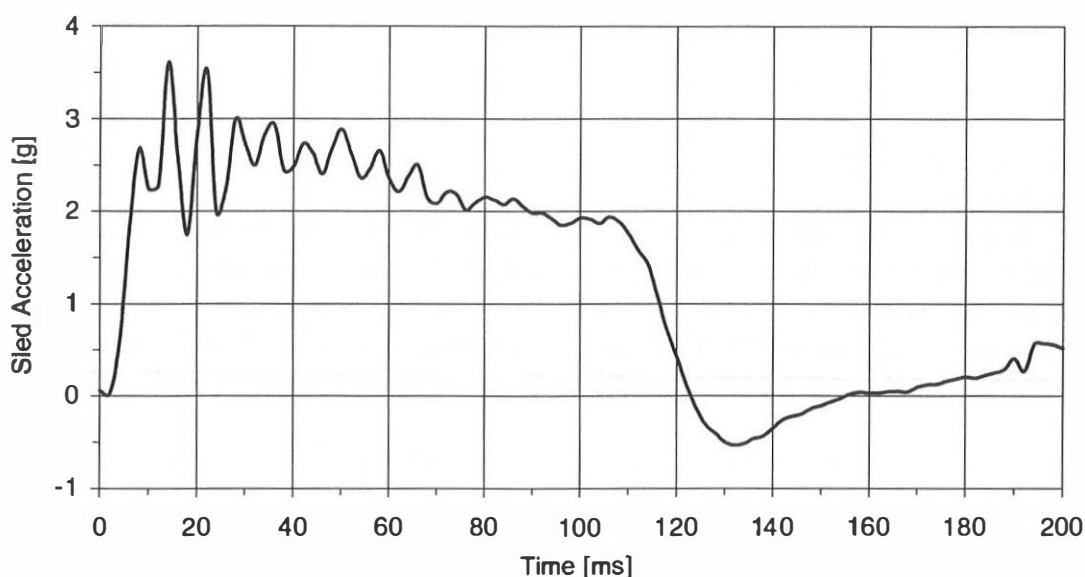
Fig. 1: Typical sled acceleration during impact

SEATS

It is well known, that the seat construction has a large influence on the acceleration behaviour of the car passengers (Geigl et al, Muser et al). To obtain a good compatibility between the tests and real accident situations, the following configuration was used.

All tests were performed using a seat from a VW Golf (Series II). To ensure a close compatibility to real accidents, a seat from an used car was mounted on the sled. Due to the low impact velocity and the low accelerations no deformation or change in stiffness or elasticity could be observed during the experiments. This was verified by comparing two identical tests at the beginning and the end of the series.

TEST OBJECTS

The tests were performed with the following test objects:
- Volunteers (mainly students in the age of 20 to 30; male and female)
- PMTO´s (mainly older persons in the age of 50 to 70; male and female)
- a Hybrid III dummy (50 %) equipped with a standard neck
- a Hybrid III dummy (50 %) equipped with a RID-Neck (Svensson et al,1992)

The RID neck tests were performed with two different bending stiffness'. For the first tests, the same bending stiffness was selected for all intervertbral disc elements. Within a second set of experiments, the bending stiffness between C0-C1 and C1-C2 was reduced by approximately 50 %. In this publication only the results of the second series are presented.

TEST DOCUMENTATION

The movement of head neck and torso was documented using a high speed Video Camera (Kodak Ekta Pro 1000). A frame rate of 1000 pps was used. In parallel, acceleration measurements were performed using 3- axis Endevco accelerometers.

The head accelerometer was mounted in the centre of gravity of the head for the dummy tests. For the volunteer tests the head accelerometer was mounted near the estimated centre of gravity of the head with respect to the side view. The torso accelerometer for the volunteers was mounted in front of the chest, approximately at the same height as the torso accelerometer of the dummy.

Fig 2 shows the mounting of both accelerometers for a volunteer.

Headaccelerometer

Torsoaccelerometer
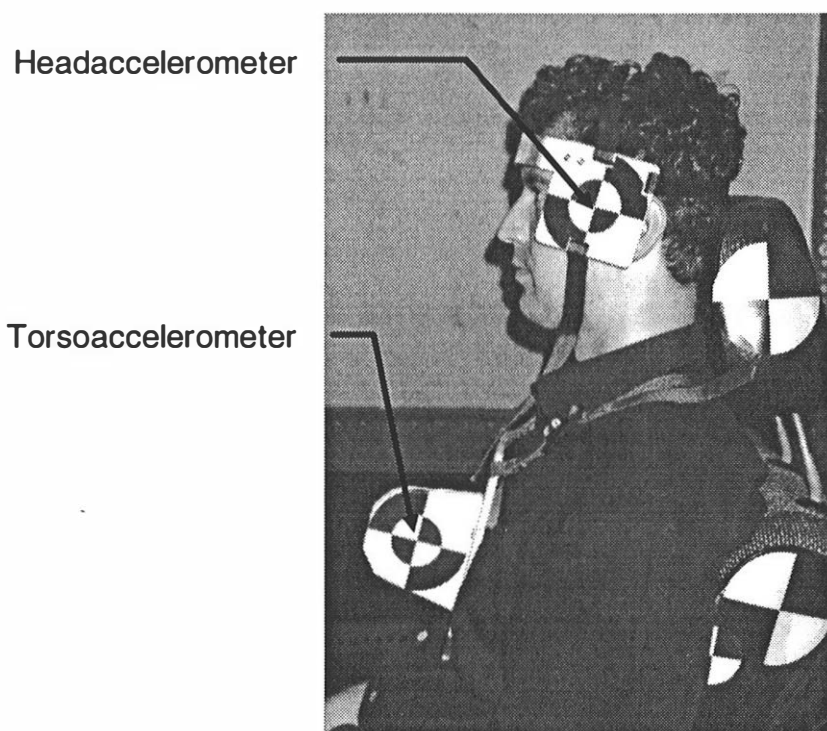
Fig. 2: Mounting of accelerometers for a volunteer

RESULTS

VOLUNTEER TESTS

Figure 3 shows the typical sled, head and torso accelerations for a volunteer test. For this test the impact velocity was 9 km/h and the mean acceleration level approximately 3 g. This results in a remaining deformation of approximately 120 mm for the friction element. The test was performed using the seat of a VW Golf II. The initial horizontal gap between head and head restraint was approximately 30 mm.
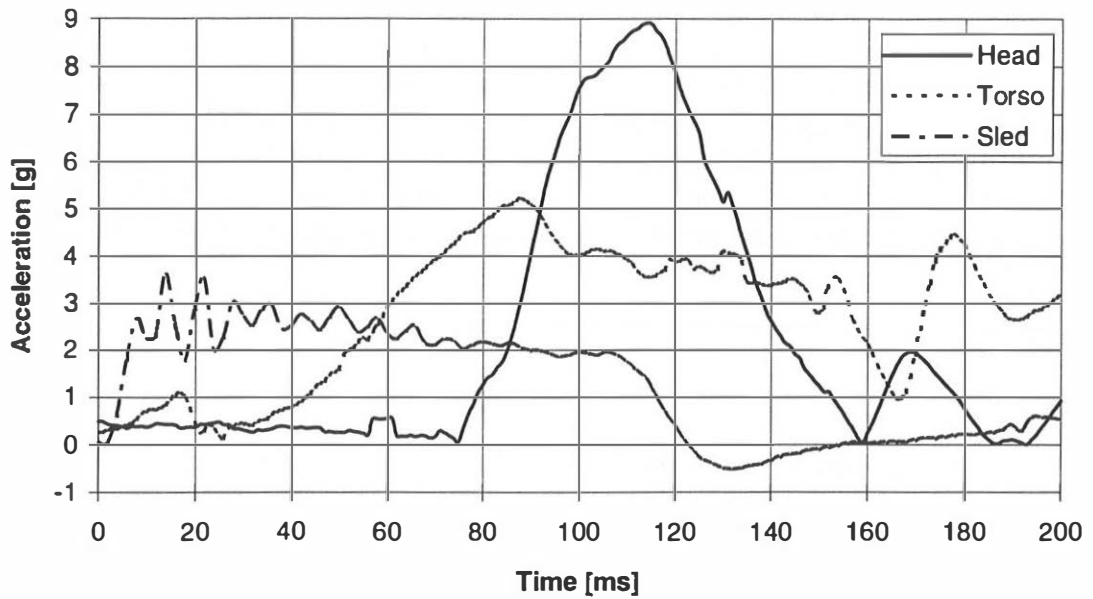
Fig. 3: Volunteer test for a Golf II seat

In this case the peak head accelerations are three times higher than the mean sled acceleration. The maximum acceleration of the torso reaches approximately 2 times the mean sled acceleration.
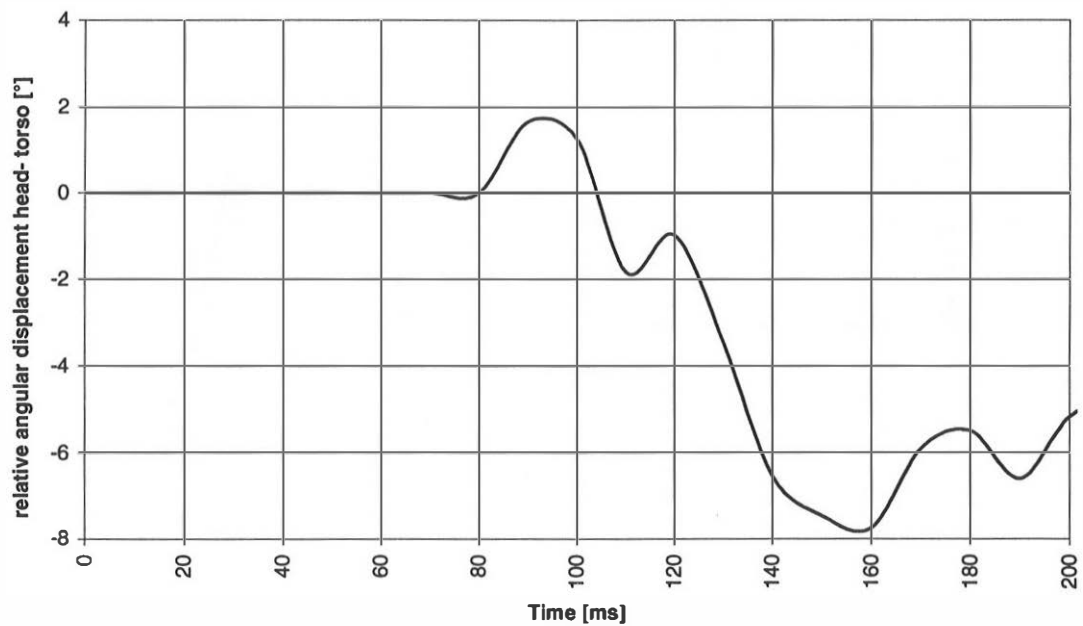

Fig. 4: Relative angular displacement between head and torso

To compare the head rotation of the different tests all video films were digitised and the rotation angles of head and torso were measured from these images at time increments of 10 ms. Figure 4 shows the relative angular displacement between head and torso for the same test as shown above.

For all these tests the following characteristic angular displacement could be found:

Approximately 60 to 80 ms after impact, a flexion started. The maximum flexion angle could be found to be in a range of 2 to 6 degrees. Between 100 and 120 ms the flexion changed into an extension. It could be seen, that the maximum extension angle mainly depended on the initial gap between head and head restraint. This maximum extension angle was found to lie between 5 and 25 degrees. The angle of 5 degrees could be seen, when the head initially contacted the head restraint. The value of 25 degrees occurred for an initial gap of 50 mm.

Dummy Tests

Figure 5 shows the comparison of the head accelerations for a Standard Hybrid III dummy and a Hybrid III dummy equipped with a RID neck. For all tests, conditions similar to those for the volunteer tests were selected. The impact velocity was 9 km/h, the mean acceleration was approximately 10 % higher than for the volunteer test.
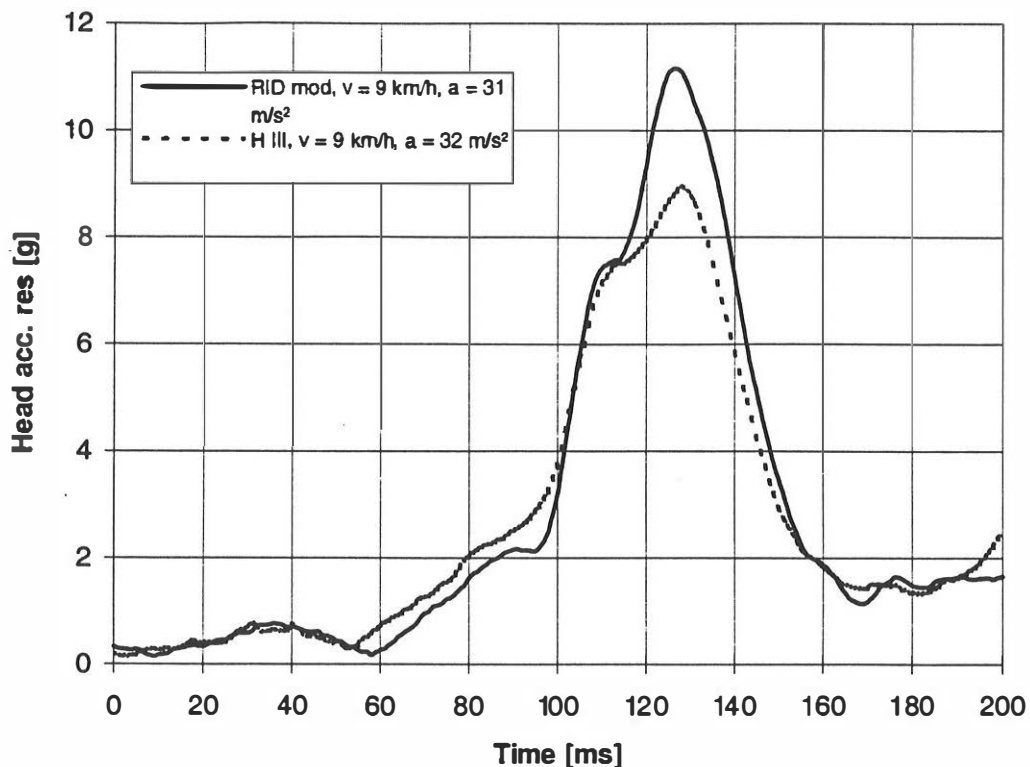

Fig. 5: Comparison of head accelerations for HIII and RID neck

Another difference between the volunteer test and the dummy test resulted from the fact, that for the dummy tests the horizontal gap between head and head restraint was always close to 80 mm. This value could not be further

reduced, due to the mounting of the neck to the dummy. For the volunteers this value was varied in the range between 0 and 50 mm. This variation can also be seen in the time delay for the peak head acceleration, which is approximately 110 ms for the volunteer test with 30 mm initial gap and 130 ms for the dummy tests.

The reason for the higher peak acceleration of the RID neck in comparison to the standard HIII neck lies in the lower bending stiffness of the RID neck. So the head mounted on the RID neck is less accelerated in the early impact phase.

Comparing head rotation the following results were found:
Figure 6 shows a comparison of head rotation between HIII and RID Neck. The most important difference is, that the standard HIII does not show any flexion. In this case the head rotation starts 40 ms after impact with an extension. This fact completely differs to the volunteer tests. 120 ms after impact, when the flexion changed to an extension for the volunteers, an extension angle of more than 20 degrees could be seen for the HIII neck.

For the RID neck a low degree of flexion could be seen, lasting up to approximately 80 ms. Later on an extension started reaching an even slightly higher peak value than the HIII neck.
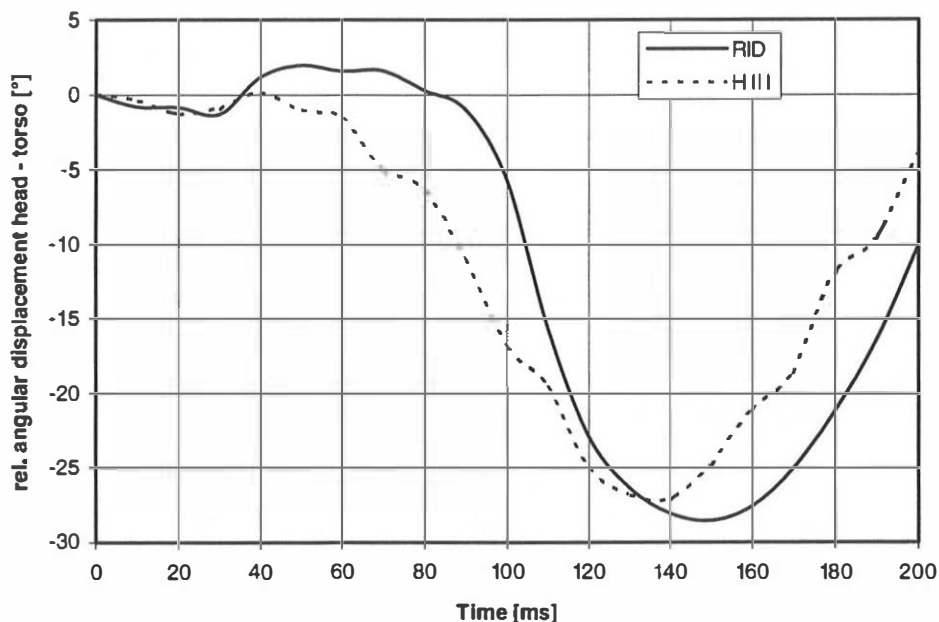

Fig. 6: Comparison of angular displacement head- torso for HIII and RID neck

PMTO Tests

Based on the PMTO tests the movement of single vertebrae could be compared to the motion of the dummy necks.

The determination of the angular displacement of the vertebrae for the PMTOs was documented in (Geigl et al, 1994). These values were compared to the rotation of the corresponding elements of the RID neck. The angular displacement of the standard HIII neck was determined from the change of the tangential to the neck at the corresponding locations.

The following diagrams show the comparison of angular displacement Head - C3 for the PMTO, a HIII- and a RID neck. These tests were performed at impact velocities of 11 km/h and a mean sled acceleration of 6 g. The high angular displacement for the PMTO resulted from a initial gap between head and head restraint of 100 mm.
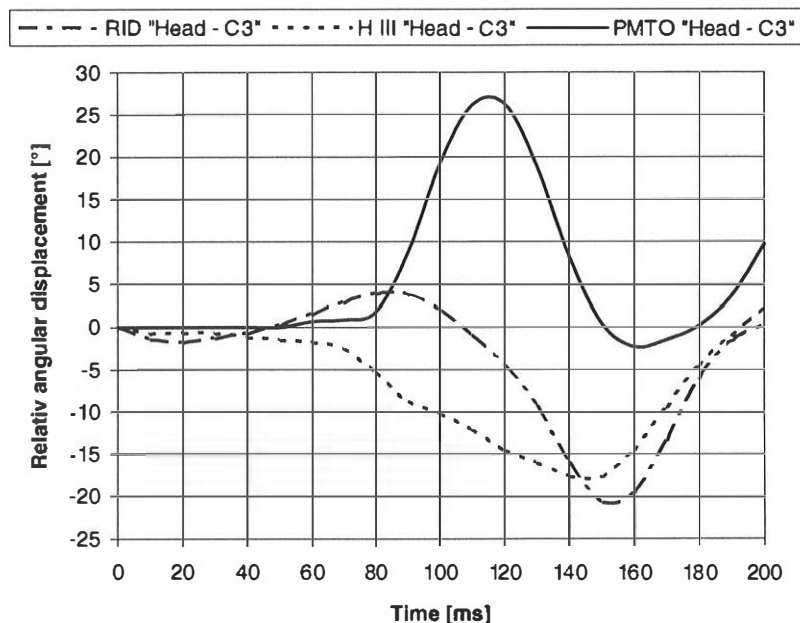

Fig. 7: Comparison of angular displacement head- C3 for HIII, RID neck and PMTO

When comparing these values it has to be taken into account, that the initial conditions, especially the initial head rotation is not identical for the three variants.

But it can be seen, that the eigen frequency of the whole neck system seems to correlate well between PMTO and RID. The high degree of flexion between head and upper cervical spine for the PMTO is not predicted well by the RID neck. The reason for this fact can be seen in Fig. 8. The PMTO shows a nearly parallel movement of the head in the time between 80 and 110 ms. In this phase the vertebrae rotate by an angle of approximately 25 degrees to allow the relative movement between head and torso.
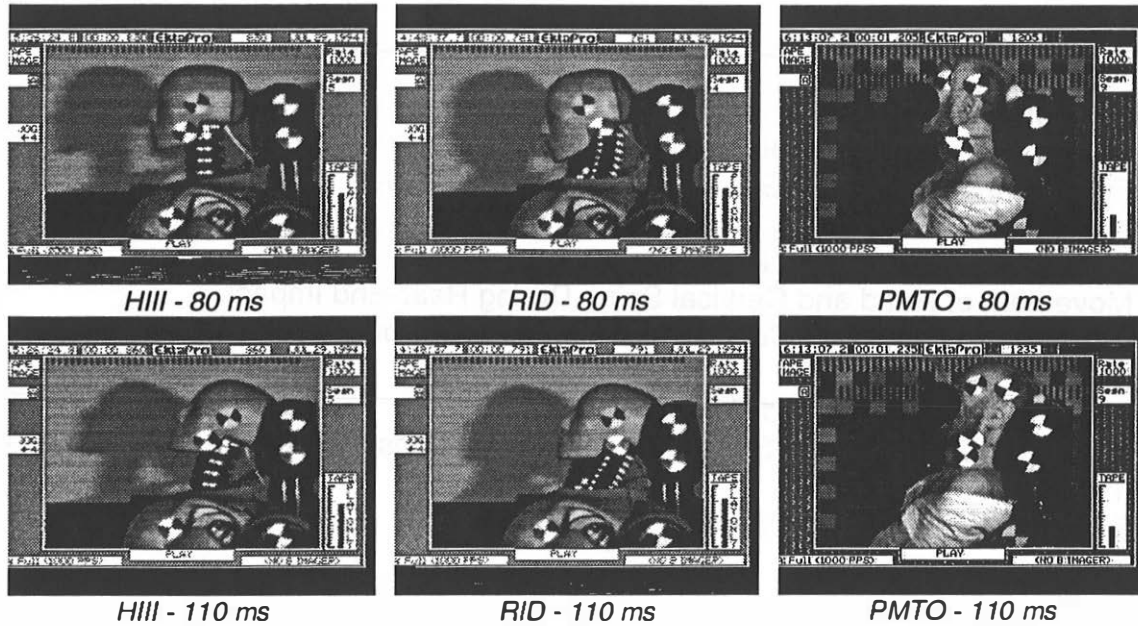
| HIII - 80 ms | RID - 80 ms | PMTO - 80 ms |
| HIII - 110 ms | RID - 110 ms | PMTO - 110 ms |

Fig. 8: Comparison of movement

For both dummy necks any translatoric movement between head and torso results in a head rotation.

Another effect which can be seen for the RID is, that due to the weak stiffness of this neck a slight oscillation of the vertebras is originated from the inhomogeneous movement of the sled. This oscillation may interact with the movement of head and neck during the impact.

DISCUSSION AND CONCLUSION

The intention of this study was to compare the head-neck kinematics between standard Hybrid III, RID Neck, Volunteers and PMTOs under similar rear end impact conditions by means of various sled tests.

These sled tests showed that movement of Head and Neck of the Standard Hybrid III were quite different compared to Volunteers and PMTOs. This fact is also well documented e.g. by Scott and McConnell et al (1993).

The RID Neck seems to be better regarding biofidelity, but as several degrees of freedom are still missing compared to the human cervical spine, further improvements can still be made.

The significant high degree of flexion between head and upper cervical spine during the PMTO test couldn't be observed for both dummy necks.

Bending of the thoracic spine in volunteers and PMTO's appears to influence head and neck motion and this cannot be reproduced by the rigid thoracic spine of the Hybrid III dummy.

Another problem which arose during these tests was the insufficient modelling of the initial lordosis of the cervical spine in all dummy necks.

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