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Thomas F. Fugger, Jr. and Bryan C. Randles
Accident Research and Biomechanics, Inc

Judson B. Welcher and Thomas J. Szabo
Biomechanical Research and Testing, LLP

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Thomas F. Fugger, Jr. and Bryan C. Randles
Accident Research and Biomechanics, Inc

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ABSTRACT

In past years, considerable research has been devoted to occupant response in a variety of low-velocity, bumper-to-bumper impacts. In many crashes, however, the involvement of a braking vehicle or a higher ground clearance vehicle results in an override/underride type crash. The amount of vehicle damage can be significantly greater during such an impact because of the involvement of non-structural components above and below the bumper systems of the involved vehicles.

Ten tests were conducted using five target vehicles, each occupied by an instrumented female driver. Each vehicle was tested in a bumper-to-bumper impact and then an override/underride configuration in increasing severity. An independent body shop estimator was employed to document the damage and prepare repair estimates for each test. In each test the vehicle and occupant accelerations were monitored. A comparison of these data collected is presented herein to provide additional insights into override/underride crashes versus bumper-to-bumper impacts.

INTRODUCTION

The dynamics and occupant kinematics of low velocity rear-end impacts have been the subject of numerous studies [1-6]. Most of those studies have been performed using vehicles impacted directly on the bumper. Szabo and Welcher [6] conducted tests in which Ford Escorts underwent bumper-to-bumper impacts, or override/underride impacts. They found increased damage in the latter impacts, and decreases in some kinematics for the target vehicle. No occupants were tested.

Gabler and Hollowell [7] conducted research on the aggressivity of higher ground clearance (HGC) vehicles. Crash incompatibilities were found to be due to three primary factors: mass, stiffness and geometry. Differences in vehicle geometry often result in an override/underride crash with a passenger vehicle.

Croteau, et al., [8] conducted override rear-end impact crash tests. These tests showed that the damage energy for vehicles having override damage up to the C-pillars can be estimated using 100% of the energy from crush at the bumper level and 50% of the energy from the additional crush at a level above the bumper.

Goodwin, et al., [9] looked at vehicle and occupant response in low speed car to barrier override impacts. In these tests, vehicles were propelled into a fixed barrier in either the front or rear direction. Two tests, the second test at a higher speed than the first, were conducted into a flat barrier that simulated a bumper impact. A second series of tests were conducted with a raised barrier so that the bumper structure was missed. Occupants within the vehicles were instrumented and it was found that the level of acceleration experienced by the occupant of the override crashes was lower than the corresponding bumper-to-bumper impact. The reduction in acceleration was attributed to a reduction in velocity change due to lower restitution of the override sheet metal components versus the bumper system.

In many crashes a bumper-to-bumper impact does not occur. When a bullet vehicle brakes prior to impacting a target vehicle, an underride/override impact often occurs. Also, vehicles with a HGC are becoming more prevalent on the highways and the alignment between HGC vehicles and passenger cars also result in crashes wherein the bumper system of one vehicle is not engaged. Since these impacts involve components that are above and below the vehicle bumpers, the override/underride impact can result in significantly more property damage to one or both of the vehicles.

In the present study, ten tests were conducted to compare vehicle damage and occupant response in bumper-to-bumper versus override/underride impacts.

METHODS

COORDINATE SYSTEM - All acceleration axis systems were in accordance with SAE J211/1 Recommended Practice and SAE J1733 Information Report with the positive X, Y and Z axes forward, rightward and downward, respectively [10,11]. The SAE sign convention dictates that cervical flexion of the spine is negative and cervical extension is positive.

HUMAN SUBJECTS – Five female volunteers (24.2 ± 1.9 years, 160.0 ± 5.1 cm, 51.7 ± 4.6 kg) were locally recruited for the testing. The subjects had no history of back pains, neck pains or headaches. Basic anthropometric data for each subject can be found in Table 1. Each participant was subjected to two impacts, one bumper-to-bumper and one underride impact, at approximately the same impact speed. The volunteers were adequately informed of the aims, methods, anticipated benefits and potential hazards of the study. Each participant was informed that they were at liberty to abstain from participation and free to withdraw consent for participation at any time. All of the participants were financially compensated for their time during the study, with the knowledge that withdrawing from the study would not affect their compensation. The subjects submitted informed consent in writing according to the Declaration of Helsinki [12].

Subject	Sex	Age	Height (cm)	Weight (kg)
1	F	25	157.5	47.7
2	F	21	162.6	53.6
3	F	24	152.4	46.8
4	F	25	162.6	58.2
5	F	26	165.1	52.3

Table 1: Crash test subjects

Every effort was made to simulate an unanticipated impact. Potential audio cues were eliminated via portable stereo earphones playing an audiotape on high volume for several minutes prior to and during impact. Rearview and side mirrors were either removed or adjusted to eliminate visual cues and no test observers were present in the occupant's field of view. The time from last human contact with the subject to the moment of impact was also randomized, to further inhibit potential preparedness.

For each of the impacts, the subject was seated in the driver's seat and instructed to position the seat as they normally would to drive. The subjects each wore the standard lap and shoulder belt. Every effort was made to simulate a normal driving position and posture for the subjects. The target vehicle was in neutral with the driver's foot on the brake pedal at the time of impact.

Head accelerations for the occupants were obtained via three triaxial blocks of IC Sensors 3031-050 (50 g) accelerometers affixed to the head via a lightweight headband. To maximize the A/D range for the output voltage of the sensor, the accelerometers were gain adjusted to collect within a range of ±20 g. The headband was made of rubber which, when tightly fastened to the subject's head, formed a secure bond.

Thorax and lumbar accelerations were obtained using two specially developed low profile (<1 cm) triaxial blocks of accelerometers that were constructed using two Entran EGAXT-50 accelerometers and one IC Sensors 3031-050 accelerometer, also gain adjusted for a ±20 g range. One of the low profile accelerometers was affixed to the occupant with medical adhesive at the approximate level of C7-T1 on the anterior torso, while the other was attached to the base of the subject's lumbar spine at the approximate location of L5-S1.

VEHICLES – Five vehicles were used in this series of rear-end impacts. A summary of the vehicles and their test weights can be found in Table 2. Vehicle modifications included removal of the driver and passenger front (where applicable) doors to facilitate video recording of the occupant motion and the removal of the center console and carpeting for sensor placement.

Year	Make	Model	VIN	Weight (kg)
1984	Dodge	Aries 4D	1B3BD26C1ECxxxxxx	1107.7
1987	Ford	Escort 2D HB	1FAPP23J7HWxxxxxx	1040.5
1987	Honda	Accord 4D	JHMCA562XHCxxxxxx	1090.5
1996	Acura	Integra 2D HB	JH4DC4345TSxxxxxx	1045.5
1989	Acura	Integra 2D HB	JH4DA3350KSxxxxxx	1062.3

Table 2: Crash test vehicles

A fifth wheel (Biomechanical Research and Testing) connected to an A/D converter and liquid crystal display (Diversified Technical Systems [DTS]) was used to ensure the desired bullet vehicle impact speeds. A time trap (DTS Timer Interval Meter) triggered by pressure sensitive tape switches (Tape Switch Corporation Type 102A) recorded the bullet vehicle's velocity immediately prior to impact. A triaxial array of accelerometers (IC Sensors 3031-050) was affixed to both the bullet and target vehicles' approximate static center of gravity. The accelerometers attached to the test vehicles were also gain adjusted for a ±20 g range.

The damage to the bullet and target vehicles was assessed after each impact by an independent appraiser. The appraiser was instructed to prepare a damage estimate under the assumption that there was no prior damage to the vehicle components involved in the subject crash. Therefore, if a vehicle part was damaged in a bumper-to-bumper impact but was deemed unlikely to have been damaged in the subsequent override/underride impact, then it should not be included in the override/underride repair estimate. Estimates were obtained for repairs using both used and original equipment manufacturer (OEM) parts, when the use of either was deemed appropriate by the adjustor.

TEST PROCEDURE – Two impacts were performed to the rear of each of the vehicles. The impact speeds were based on approximate Delta V's ranging from 3.2 to 9.6 kph (2 to 6 mph) calculated using an assumed coefficient of restitution. The first impact in each of the five series was a bumper-to-bumper impact. The second impact was an underride impact run as close to the impact velocity of the previous collision as possible. The underride condition was created by placing the target vehicle on wood planks. The planks consisted of 2 x 10 and 4 x 10 boards stacked at an appropriate height to create the override/underride condition. Exemplar side views of the override/underride test setup can be seen in the photographs in Figure 1.

Figure 1: Exemplar pre-test override/underride configurations

DATA ACQUISITION AND POST PROCESSING - All data were collected following the general theory of SAE Recommended Practice: Instrumentation for Impact Test - J211/1 Mar95 [10]. All accelerometer data were collected at 1000 Hz. Vehicle changes in velocity were calculated from vehicle acceleration data filtered with an SAE Class 180 filter. Occupant acceleration data were filtered with an SAE Class 60 filter in accordance with previous research [13].

Displacements of the head relative to the vehicle were obtained from the high-speed video (JVC DVL 9500) using the Peak Motus system (Peak Performance Technologies). The targets were tracked at 120 Hz. The digitized displacement data were filtered using a 5-point moving average filter to reduce digitizing artifacts.

RESULTS – The impact speeds, resulting Delta V's, collision durations and peak accelerations for each impact can be seen in Table 3. The use of the fifth wheel with digital readout resulted in repeatable bullet vehicle impact speeds (R^2 = 0.9999).

Test	Description	Target	Occupant	Head a_{peak} (G)	Thorax a_{peak} (G)	Lumbar a_{peak} (G)	Head -d_{max} (mm)	Time Head -d_{max} (msec)
1	Bumper-to-Bumper	Aries	1	1.74	1.56	dl	-90	183
2	Underride	Aries	1	1.84	1.64	dl	-89	183
3	Bumper-to-Bumper	Escort	2	3.62	2.36	2.25	-138	217
4	Underride	Escort	2	5.97	0.89	2.32	-111	175
5	Bumper-to-Bumper	Accord	3	8.41	3.25	2.67	-84	308
6	Underride	Accord	3	6.73	3.22	2.73	-95	158
7	Bumper-to-Bumper	96 Integra	4	8.99	5.00	4.61	-119	117
8	Underride	96 Integra	4	7.51	3.70	3.24	-116	150
9	Bumper-to-Bumper	89 Integra	5	13.06	6.64	6.08	-197	142
10	Underride	89 Integra	5	13.23	8.43	5.57	-173	125

Table 4: Occupant parameters

For each impact, the peak velocity change and peak acceleration was determined for the vehicle. Each parameter was calculated in the X-direction only, as the Y and Z components were negligible. Durations were calculated as the time at which the vehicle acceleration dropped below 5% of the peak. Average acceleration was calculated as the ratio between the Delta V and the duration of the impact. The change in kinetic energy was calculated as a function of the Delta V and the vehicle mass.

The occupant peak kinematic parameters are presented in Table 4. Head, thoracic and lumbar peak linear accelerations for the X-direction, as well as maximum head rearward displacement and time to maximum displacement are included in this table.

Damage repair estimates for both the bullet and target vehicles were prepared and are presented in Figures 1 and 2. The general trend is that the cost of repairs for the underride impact exceeds that of the bumper-to-bumper impact for both the bullet and target vehicles.

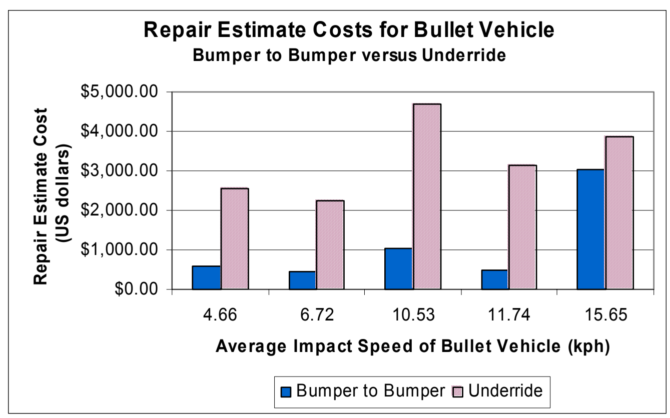

Figure 1: Repair estimates for bullet vehicle versus impact speed

Test	Description	Bullet	Impact Speed (kph)	Delta V (kph)	Duration (msec)	a_{peak} (G)	a_{avg} (G)	KE (Joules)	Target	Occupant	Delta V (kph)	Duration (msec)	a_{peak} (G)	a_{avg} (G)	KE (Joules)
1	Bumper-to-Bumper	Escort	4.63	-3.4	130	-1.7	-0.7	457.4	Aries	1	3.2	130	1.6	0.7	441.7
2	Underride	Escort	4.68	-3.7	135	-1.6	-0.8	548.6	Aries	1	3.2	135	1.8	0.7	441.7
3	Bumper-to-Bumper	Accord	6.66	dl	dl	dl	dl	dl	Escort	2	4.5	138	2.0	0.9	813.1
4	Underride	Accord	6.78	dl	dl	dl	dl	dl	Escort	2	4.5	134	2.3	1.0	813.1
5	Bumper-to-Bumper	96 Integra	10.46	dl	dl	dl	dl	dl	Accord	3	6.7	142	3.3	1.3	1917.4
6	Underride	96 Integra	10.59	-7.5	152	-3	-1.4	2302.0	Accord	3	6.6	152	3.2	1.2	1827.2
7	Bumper-to-Bumper	89 Integra	11.73	-7.4	112	-5	-1.9	2240.5	96 Integra	4	6.9	114	4.2	1.7	1926.8
8	Underride	89 Integra	11.74	-6.9	135	-3.7	-1.5	1957.8	96 Integra	4	6.9	139	3.7	1.4	1926.8
9	Bumper-to-Bumper	Accord	15.65	-9.0	105	-5.6	-2.4	3408.7	89 Integra	5	9.0	117	4.9	2.2	3320.6
10	Underride	Accord	15.64	-10.1	126	-5.7	-2.3	4314.1	89 Integra	5	9.8	126	5	2.2	3940.0

dl denotes data loss

Table 3: Vehicle crash test data

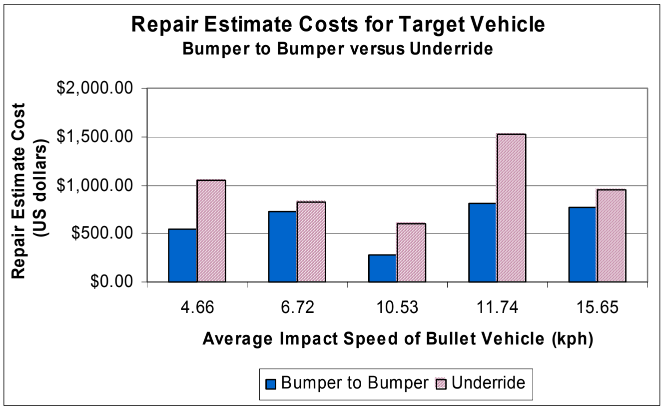

Figure 2: Repair estimates for target vehicle versus impact speed

A summary of the dollar amounts from the repair estimates for each test are presented in Table 5. For those cases where the dollar amount between an OEM and used estimate was negligible, only an OEM estimate was prepared. Further, no repair estimate for OEM parts was prepared for the 1984 Dodge Aries, as the age of the vehicle prohibited such a compilation. A summary of the major parts to be repaired/replaced for each vehicle is provided in Appendix A.

Test	Description	Bullet	Delta V (mph)	Repair Est OEM	Repair Est Used	Target	Delta V (mph)	Repair Est OEM	Repair Est Used
1	Bumper-to-Bumper	Escort	-2.1	$693.12	$573.20	Aries	2	*	$548.92
2	Underride	Escort	-2.3	$2,669.83	$2,547.67	Aries	2	*	$1,055.29
3	Bumper-to-Bumper	Accord	dl	$445.00	*	Escort	2.8	$1,060.26	$728.84
4	Underride	Accord	dl	$2,241.32	*	Escort	2.8	$1,443.58	$820.03
5	Bumper-to-Bumper	96 Integra	dl	$1,032.44	*	Accord	4.2	$280.29	*
6	Underride	96 Integra	-4.7	$4,683.40	*	Accord	4.1	$728.44	$604.65
7	Bumper-to-Bumper	89 Integra	-4.6	$541.42	$479.94	96 Integra	4.3	$810.66	*
8	Underride	89 Integra	-4.3	$3,336.01	$3,140.40	96 Integra	4.3	$1,834.24	$1,526.66
9	Bumper-to-Bumper	Accord	-5.6	$3,337.49	$3,034.51	89 Integra	5.6	$828.83	$764.81
10	Underride	Accord	-6.3	$4,203.89	$3,865.74	89 Integra	6.1	$1,156.12	$946.61

* estimate not prepared

Table 5: Repair estimate comparisons

DISCUSSION

The use of the fifth wheel with digital display provided a reliable method for controlling the impact speed of the bullet vehicle. This allowed good replication of the change in velocity for the bumper-to-bumper versus override/underride tests. As expected, there was a strong correlation for both the bullet and target Delta V versus impact speed with R^2 values of 0.960 and 0.987, respectively.

The target vehicle Delta V, peak accelerations, average accelerations and kinetic energy were not found to be significantly different for the underride versus bumper-to-bumper impacts for a given impact speed. A plot of Delta V versus collision duration of the target vehicle is presented in Figure 3. For both the bumper-to-bumper and override/underride impacts the durations decrease slightly with increasing impact severity. Further, it appears that higher severity override/underride impacts result in slightly longer durations than their bumper-to-bumper counterparts, while similar durations were found for the lower severity impacts.

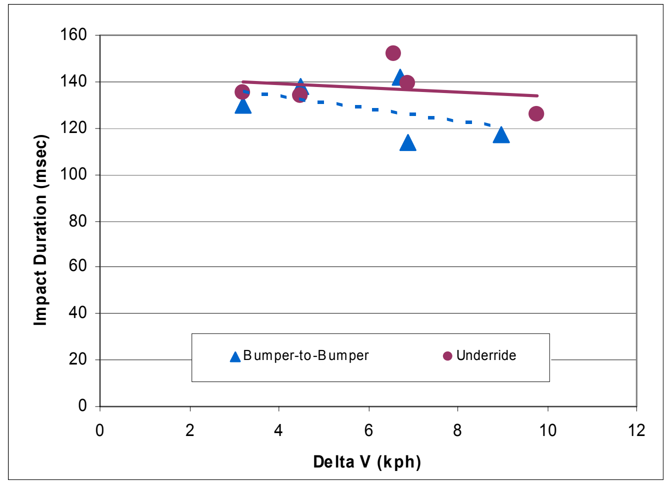

Figure 3: Target Delta V versus collision duration

The restitution values for each impact were calculated using two different methods for calculating conservation of momentum. The values for e_v were calculated using the Delta V from both vehicles and the closing speed. The restitution coefficients, e_b and e_t, were calculated using the Delta V of the bullet or target vehicle, closing speed for the impact and the mass ratio of the two vehicles for each impact. The resulting restitution values are presented in Table 6. As seen in previous studies, the general trend of the coefficient of restitution decreased as the impact speed of the target vehicle increased.

Test	Description	Bullet	Target	Restitution e_v	Restitution e_b	Restitution e_t
1	Bumper-to-Bumper	Escort	Aries	0.42	0.41	0.43
2	Underride	Escort	Aries	0.47	0.53	0.41
3	Bumper-to-Bumper	Accord	Escort	dl	dl	0.32
4	Underride	Accord	Escort	dl	dl	0.29
5	Bumper-to-Bumper	96 Integra	Accord	dl	dl	0.31
6	Underride	96 Integra	Accord	0.33	0.39	0.27
7	Bumper-to-Bumper	89 Integra	96 Integra	0.22	0.27	0.17
8	Underride	89 Integra	96 Integra	0.17	0.18	0.16
9	Bumper-to-Bumper	Accord	89 Integra	0.15	0.16	0.13
10	Underride	Accord	89 Integra	0.27	0.31	0.23

Table 6: Coefficient of restitution data

The damage sustained by the vehicles was greater for the override/underride crash tests than the bumper-to-bumper tests, especially for the bullet vehicles. The pre and post-impact condition of the bullet vehicle for Tests 5 and 6 are shown in Appendix B. As seen in this appendix, the front of the Acura has scuffing and nicking of the bumper cover from the bumper-to-bumper test with a repair estimate of about $1000. By contrast, the override test resulted in significant damage to the top of the bumper cover and buckling of the hood, reflected in approximately $4600 in damage.

Another example of the damage differences between a bumper-to-bumper and override/underride impact is displayed in Appendix C. The pre and post-impact conditions of the bullet vehicle for Tests 9 and 10 are shown in this appendix. The bullet vehicle (Honda Accord) had minor override damage to the front of the hood from a previous test.

There was a significant difference between repair costs in the bumper-to-bumper and underride impacts ($p \leq 0.05$) for both the bullet and target vehicles. For the override condition, the bullet vehicle's repair cost was about 4 to 6 times higher than the comparable bumper-to-bumper impact except for all but the highest impact speed. For the target vehicle, the underride/override repair estimates were approximately 1½ to 3 times more than their bumper-to-bumper counterparts.

Both the bumper-to-bumper and override/underride impacts show a near linear relationship between peak acceleration and Delta V, however for these vehicles, occupants and severities there does not appear to be a significant difference in peak head acceleration between the impact types for a given Delta V. It should be noted that head contact with the head restraint occurred in all tests except test numbers 1 and 2.

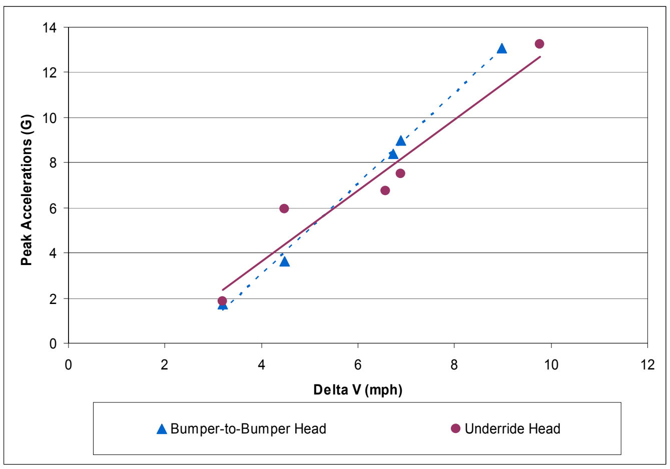

Figure 4: Peak head accelerations versus Delta V

A linear regression analysis was conducted to determine the strength of the relationship between the target vehicle parameters presented in Table 4 and the occupant kinematic parameters presented in Table 3. The correlation coefficient (R^2) and p-value are listed in Tables 7 and Table 8 for the bumper-to-bumper and underride impacts, respectively. Although most occupant kinematic parameters correlated well with the vehicle impact severity measures, no significant differences were noted when comparing the occupant kinematic peak values for the bumper-to-bumper versus override/underride impacts.

Vehicle		Head a_{peak}	Thorax a_{peak}	Lumbar a_{peak}	Head $-d_{max}$	Time Head $-d_{max}$
Delta V	R^2	0.998	0.952	0.895	-0.633	-0.221
	(p)	(0.000*)	(0.006*)	(0.052)	(0.126)	(0.360)
a_{peak}	R^2	0.981	0.977	0.939	-0.597	-0.391
	(p)	(0.002*)	(0.002*)	(0.031*)	(0.144)	(0.258)
a_{avg}	R^2	0.977	0.996	0.979	-0.706	-0.442
	(p)	(0.002*)	(0.000*)	(0.011*)	(0.091)	(0.228)
Energy	R^2	0.991	0.954	0.892	-0.676	-0.248
	(p)	(0.001*)	(0.006*)	(0.054)	(0.105)	(0.344)

* denotes significance $p \leq 0.05$

Table 7: Bumper-to-bumper occupant data

Vehicle		Head a_{peak}	Thorax a_{peak}	Lumbar a_{peak}	Head $-d_{max}$	Time Head $-d_{max}$
Delta V	R^2	0.967	0.945	0.955	-0.851	-0.994
	(p)	(0.004*)	(0.008*)	(0.022*)	(0.034*)	(0.000*)
a_{peak}	R^2	0.959	0.957	0.958	-0.869	-1.000
	(p)	(0.005*)	(0.005*)	(0.021*)	(0.028*)	(0.000*)
a_{avg}	R^2	0.983	0.918	0.998	-0.943	-0.984
	(p)	(0.001*)	(0.014*)	(0.001*)	(0.008*)	(0.001*)
Energy	R^2	0.962	0.954	0.979	-0.899	-0.988
	(p)	(0.004*)	(0.006*)	(0.011*)	(0.019*)	(0.001*)

* denotes significance $p \leq 0.05$

Table 8: Override/underride occupant data

Immediately following the crash tests one volunteer reported a minor headache. This was possibly due to the headband instrumentation as opposed to something related to the impact forces and was resolved within 24 hours. Also at the 24 hour timeframe, two other volunteers reported minor body soreness or tightness. At two days post accident, all five volunteers reported no symptoms. Follow-up was continued for 2 months and only one of the volunteers reported any periodic muscle tightness that was cyclical in the first month post testing.

CONCLUSIONS

The ten tests showed that a significantly greater level of damage, both visually and economically, resulted from the override/underride configuration. The target vehicle Delta V, peak accelerations, average accelerations and kinetic energy were not found to be significantly different for the bumper-to-bumper versus underride impacts for a given impact speed.

Ten low-speed rear-end crash tests were conducted with female occupants. Five were vehicle bumper-to-bumper alignments and five were override/underride alignments. The occupant head, thoracic and lumbar peak linear accelerations for the X-direction, as well as maximum head rearward displacement and time to maximum displacement were similar for both the bumper-to-bumper and override/underride tests. However, some divergence was observed at the higher Delta V's indicating a possible trend which should be further investigated.

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CONTACT

Thomas F. Fugger, Jr., P.E.
Accident Research and Biomechanics, Inc.
27811 Avenue Hopkins, Suite 1
Valencia, CA 91354
arb@accidentresearch.com

Judson B. Welcher
Biomechanical Research and Testing, LLC
1827 Ximeno Avenue, #2
Long Beach, CA 90815
welcher@usc.edu

APPENDIX

APPENDIX A

Test	Car	Impact	Bumper to Bumper	Underride
1 & 2	Escort	**Bullet**	*Replace:* (FB) Cover with Fog Lamps, License Bracket	***Additional-*** *Replace:* (FB) R and L Headlamp Assy, (HD) Hood, Latch, (CL) Pressure Check, (MS) Freon and Oil, Labor
	Aries	**Target**	*Replace:* (RB) R and L Guards, Reinforcement, Bumper Cover with Guards	***Additional-*** *Replace:* (RB) R and L Energy Absorbers, (MS) Labor
3 & 4	Accord	**Bullet**	*Replace:* (FB) Bumper Cover	***Additional-*** *Replace:* (HD) Hood, Front with Strip, Emblem, Lock, (FB) Grille, Center Molding, Upper Tie Bar, Baffle Center Support, (FL) R and L Molding, (AC) Pressure Check, (MS) Labor
	Escort	**Target**	*Replace:* (RB) Bumper Assembly, R and L Energy Absorber	***Additional-*** *Replace:* (RB) Cover, (EX) Replace Muffler
5 & 6	96 Integra	**Bullet**	*Replace:* (FB) Bumper Cover, Emblem, Energy Absorber, Reinforcement Bar	***Additional-*** *Replace:* (FB) R and L Bumper Cover Stiffeners Upper and Side, (FL) R and L Headlamp Assembly, (HD) Hood, (CL) Radiator Support, (FD) L Front Panel, (MS) Freon and Oil, Labor
	Accord	**Target**	*Replace:* (RB) Bumper Cover, Energy Absorber	***Additional-*** *Replace:* (RB) Bumper Cover Assembly, (EX) Repair Rear Muffler End Pipe
7 & 8	89 Integra	**Bullet**	*Replace:* (FB) Bumer Cover RS and LS, Reinforcement Upper	***Additional-*** *Replace:* (FB) Bumper Cover Assembly, (FL) L Marker Lamp, (GR) Grille Upper and Lower, (CL) Upper Tie Bar, Support Grille, L Baffle, Pressure Check, (HD) Hood, (MS) Freon and Oil, Condenser, Labor
	96 Integra	**Target**	*Replace:* (RB) ***Repair*** Bumper Cover, Replace Reinforcement Beam, R and L Energy Absorbers, Upper Reinforcement	***Additional-*** *Replace:* (RB) Rear Bumper Assembly, (EX) Muffler, Tailpipe Extension, (MS) Labor
9 & 10	Accord	**Bullet**	*Replace:* (FB) Bumper Cover Assembly, (GR) Grille, Grille Bracket, Center Molding, (HD) Hood Assembly, Front with Strip, Emblem, Lock, (FL) R Retractor, R Lid, R Molding, L Signal Lamp Assembly, (CL) Upper Tie Bar, Baffle Center Support, (AC) Condenser	***Additional-*** *Replace:* (HD) Align R and L Hinge, (FD) ***Repair*** L Fender, (FL) R and L Bezel, L Lid, L Retractor Assembly, LS Marker Lamp, (CL) Support Assembly, Radiator Manual Transmission (AC) Condenser, (MS) Labor
	89 Integra	**Target**	*Replace:* (RB) Bumper Cover RS and LS Assembly	***Additional-*** *Replace:* Muffler and Pipe

* AC= Air Conditioner and Heater, CL= Cooling, EX= Exhaust System, FB= Front Bumper, FD= Fender, FL= Front Lamps, GR= Grille, HD= Hood, MS= Miscellaneous, RB= Rear Bumper

APPENDIX B

Test Number 5 pre-test photos.

Test Number 5 post-test photos.

Test Number 6 post-test photos.

APPENDIX C

Test Number 9 pre-test photos.

Test Number 9 post-test photos.

Test Number 10 post-test photos.