Advanced Occupant Protection/Knee Air Bag Investigation/Vehicle to Objects
Dynamic Science, Inc./Case Number: DS06017
2005 Toyota Avalon
Arizona
July 2006

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics in order to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants.

Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) or their safety systems.

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16. Abstract

This on-site investigation focused on the advanced occupant protection/knee air bag system in a 2005 Toyota Avalon. This single vehicle crash occurred in July 2006 at 1834 hours in a rural area of Arizona. The case vehicle was a 2005 Toyota Avalon four-door sedan being driven by a 46-year-old male. The crash occurred at the intersection of a three lane street and an interstate highway frontage road. The Toyota Avalon was traveling south in the center lane of the three lane, two way street and was approaching the intersection. As the driver approached the intersection, he began to experience some type of medical episode. The Avalon approached the intersection at a high rate of speed, continued south without stopping and crossed over the frontage road. The Avalon drove through a wire fence that was adjacent to the roadway. The Avalon continued south, traveled over the westbound lanes of the interstate and off the south edge of the highway. The Avalon traveled up a sloped median separating the east and westbound interstate lanes causing it to become airborne. The Avalon landed on the interstate's eastbound travel lanes. The Avalon continued south, traveled across the eastbound highway lanes and onto another dirt and sand median separating the eastbound interstate lanes and another frontage road. The front of the Avalon struck another wire fence located in the median, then traveled onto the frontage road. It crossed the two frontage road lanes and traveled off the south roadway edge. The Avalon traveled a short distance south of the roadway edge and struck a utility pole with its front end, resulting in the deployment of the driver's front and knee air bags and the actuation of the driver's seat belt pretensioner. The driver was transported by ambulance to a trauma center where he was hospitalized for three days with a cerebral concussion, a compression fracture of his L1 disc, and abrasions to his upper left chest and lower left leg. The vehicle was towed from the scene and later declared a total loss.

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Dynamic Science, Inc.
Crash Investigation
Case Number: DS06017

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BACKGROUND:

This on-site investigation focused on the advanced occupant protection/knee air bag system in a 2005 Toyota Avalon. This single vehicle crash occurred in July 2006 at 1834 hours in a rural area of Arizona. The case vehicle was a 2005 Toyota Avalon four-door sedan being driven by a restrained 46-year-old male. There were no other occupants in the vehicle. The crash occurred at the intersection of a three lane street and an interstate highway frontage road. This was a T-intersection.

Figure 1. Front - 2005 Toyota Avalon

The Avalon was traveling south in the center lane of the three lane, two way street and was approaching the intersection. Traffic on the east/west frontage road is not controlled but the two southbound roadway lanes are controlled by a posted stop sign. As the driver approached the intersection, he began to experience some type of medical episode. This driver has a past history of seizures. The Avalon approached the intersection at a high rate of speed, continued south without stopping and crossed over the frontage road. The Avalon drove through a wire fence that was adjacent to the roadway, damaging the right side of the vehicle. The Avalon continued south, traveled over the westbound lanes of the interstate and off the south edge of the highway. The Avalon traveled up a sloped median separating the east and westbound interstate lanes causing it to become airborne. The Avalon landed on the interstate's eastbound travel lanes, damaging the vehicle's undercarriage. The Avalon continued south, traveled across the eastbound highway lanes and onto another dirt and sand median separating the eastbound interstate lanes and another frontage road. The front of the Avalon struck another wire fence located in the median, then traveled onto the frontage road. It crossed the two frontage road lanes and traveled off the south roadway edge. The Avalon traveled a short distance south of the roadway edge and struck a utility pole with its front end, resulting in the deployment of the driver's front and knee air bags and the actuation of the driver's seat belt pretensioner. The Avalon rotated clockwise and came to final rest off the roadway, facing northwest.

Figure 2. Right rear damage - 2005 Toyota Avalon

The driver was conscious when police arrived. He was transported by ambulance to a trauma center where he was hospitalized for three days with a cerebral concussion, a compression fracture of his L1 disc, and abrasions to his upper left chest and lower left leg. While at the hospital, the investigating officer discovered that the driver had a history of seizures and takes medication for them. He reported to police that "all he remembered was that he was traveling south and he blacked out". During the SCI driver interview, he reported that during the pre-crash phase, he either fell asleep or experienced a hallucination. During this episode, his right foot pressed down hard on the accelerator. The driver estimated his pre-crash and impact speeds as 129 km/h (80 mph).

The impact between the case vehicle and the pole resulted in disabling engine damage. The vehicle was towed from the scene and later declared a total loss.

This case was identified within a group of potential cases provided to the NHTSA. DSI received a fax on August 25, 2006 with instructions to locate the vehicle. The vehicle was located and DSI was assigned the case on August 28, 2006. Field work was completed that week. This crash was originally assigned as a Certified Advanced 208-Compliant (CAC) Investigation case, but during the vehicle inspection, it was determined that this vehicle was not equipped with CAC air bags.

SUMMARY

Crash Site

This single vehicle crash occurred in July 2006 at 1834 hours in a rural area of Arizona. The crash occurred at the intersection of a three lane street and an interstate highway frontage road. This was a T-intersection. The three lane asphalt roadway had two southbound lanes and one northbound lane. At the intersection with the frontage road, the curb lane of the southbound street becomes a right-turn-only lane and the center lane becomes a left turn only lane. The two lanes are separated by a solid white lane line. The two southbound lanes are separated from the northbound lane by yellow painted, no passing double lane lines. This roadway is level, has no curbs and the shoulders consist of sand and dirt.

Figure 3. Approach of 2005 Toyota Avalon to roadway departure point (south)

Figure 4. Case vehicle impacts first fence (south)

The intersecting frontage road was comprised of three asphalt travel lanes. There are two eastbound lanes and one westbound lane. The eastbound lanes are separated from one another by a dashed white lane line. The east and westbound lanes are separated from one another by yellow painted, no passing double lanes lines. This frontage road had no curbs and the north shoulder consisted of sand, dirt and scattered shrubs. On the south side of the roadway, there was a sand and dirt median with a wire fence that ran east/west. The fence consisted of four wires held up by small diameter metal poles. The median had an uphill grade. South of the median, there were two westbound interstate highway lanes with no curbs. The lanes were separated from one another by a painted dashed white lane line. South of these lanes was another sand and dirt median. This median had an uphill grade. South of the median were two eastbound interstate highway lanes with no curbs. The lanes were separated from one another by a painted dashed white lane line. South of these lanes was another dirt and sand median. Within the median was another wire fence. The wire fence consisted of four wires held up by small diameter metal poles. South of the median was another frontage road with no curbs. This frontage road consisted of one eastbound and one westbound lane, separated from one another by a yellow dashed lane line. South of the frontage road was a gravel, dirt and sand shoulder. Just south of the shoulder was a utility pole. The area surrounding the pole consisted of dirt, sand and scattered shrubs.

Figure 5. Vehicle continues south, approaching another roadway (south)

Figure 6. Vehicle continues south and impacts a utility pole (south)

On the northernmost frontage road, east and westbound traffic is not controlled, but the intersecting southbound roadway lanes are controlled by a posted stop sign. At the time of the crash it was daylight, there were no visual obstructions present and all of the roadways were dry. The posted speed limit for the roadway the case vehicle was first traveling on was 56 km/h (35 mph).

Pre-Crash

The case vehicle was a 2005 Toyota Avalon four-door sedan being driven by a restrained 46-year-old male. There were no other occupants in the vehicle. The case vehicle was traveling south in the center lane on the three lane, two way street and was approaching the frontage road intersection.

Crash

As the driver approached the intersection, he may have suffered a seizure. The Avalon continued traveling south through the intersection without stopping, crossed over the frontage road and the drove through the wire fence, damaging the right side of the vehicle (12RZES1). The Avalon continued south, traveled over the westbound lanes of the interstate and off the south edge of the highway. The Avalon traveled up the sloped median separating the east and westbound interstate lanes, causing the vehicle to become airborne. The case vehicle landed on the interstate's eastbound lanes, damaging the vehicle's undercarriage (00UDDW2). The Avalon continued south, traveled across the eastbound lanes and onto the dirt and sand median separating the eastbound interstate lanes and the second frontage road. The front of the Avalon struck another wire fence (12FLMS6) located in the median, then traveled onto the frontage road. It crossed the two frontage road lanes and traveled off the south roadway edge. The case vehicle traveled a short distance south of the roadway edge and struck a utility pole with its front end (12FZEW3), resulting in the deployment of the driver's front and knee air bags and the actuation of the driver's seat belt pretensioner. The barrier routine of the WinSmash program computed a delta V of 39.0 km/h (24.2 mph)[1].

Figure 7. Looking back from the utility pole to the impacted fences and pre-crash roadway (north)

After the pole impact, the Avalon rotated clockwise and came to final rest off the roadway, facing northwest.

Post-Crash

The driver was conscious when police arrived. He was transported by ambulance to a local trauma center where he was hospitalized for three days with a cerebral concussion, a compression fracture of his L1 disc, a facial laceration and abrasions to his upper left chest and lower left leg.

At the hospital, the investigating officer learned that the driver suffers from seizures and takes medication for them. The Toyota Avalon was towed from the scene due to damage and was later declared a total loss.

[1]Results are borderline due to yielding object. Results are provided for informational purposes only.

Vehicle Data - 2005 Toyota Avalon

The 2005 Toyota Avalon was identified by the Vehicle Identification Number (VIN): 4T1BK36B05Uxxxxxx. The Avalon is a four door sedan with seating for five. The vehicle's odometer could not be read because there was no power to the instrument panel at the time of the inspection. The driver estimated the vehicle mileage as 35,406 km (22,000 miles). The case vehicle was equipped with a 3.5 liter six-cylinder engine, a five speed automatic transmission, four wheel anti-lock brakes, daytime running lights and a tilt steering wheel.

Figure 8. 2005 Toyota Avalon exemplar vehicle

The 2005 Toyota Avalon was equipped with Michelin Energy MXV4 P215/55R17 tires. The vehicle manufacturer's recommended cold tire pressure was 220 kPa (32 psi) for the front and rear. The listed maximum tire pressure was 303 kPa (44 psi). The specific tire information is as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	207 kPa (30 psi)	3 mm (4/32 in)	No	None
LR	228 kPa (33 psi)	6 mm (7/32 in)	No	None
RR	414 kPa (60 psi)	6 mm (7/32 in)	No	None
RF	221 kPa (32 psi)	2 mm (3/32 in)	Yes	None

The front row seating in the Avalon was configured with dual leather covered bucket seats. The seats were equipped with adjustable head restraints that were not damaged. The second row was configured as a leather covered bench seat with reclining seat backs. All three second row seating positions were equipped with adjustable head restraints that were not damaged. The second row outboard seating positions were equipped with the lower anchor points that are part of this vehicle's Lower Anchors and Tethers for Children (LATCH) system and all three seating positions were equipped with child safety seat top tether anchor points, located on the hat shelf behind the seat backs.

Vehicle Damage

Exterior Damage - 2005 Toyota Avalon

Damage Description: There were three separate front end impacts to the case vehicle. Two of the impacts involved lightweight wire fences consisting of four evenly spaced wires attached to small metal poles. The two impacts between the Toyota Avalon and the fences resulted in minor front and right side vehicle damage. The front of the case vehicle sustained 9.0 cm (3.5 in) of direct damage to the hood, beginning 23.0 cm (9.1 in) right of the left front bumper corner, extending to the right. The damage consisted mostly of superficial scrapes and scratches. The Collision Deformation Classification (CDC) for this impact was 12FLMS6.

Figure 9. End of right rear damage

It appears that the case vehicle sideswiped one of the fence posts, resulting in minor right side damage. The Avalon sustained 130.0 cm (51.2 in) of direct damage along the right side of the vehicle beginning 38.0 cm (15.0 in) forward of the left rear axle, extending forward. The maximum lateral crush from this crash event was 3.0 cm (1.2 in). The location of maximum crush was above the right rear tire. The CDC for this impact was 12RZES1.

Figure 10. Beginning of right rear damage

The Avalon sustained light damage to the undercarriage as a result of impacting the roadway during the crash events. The left muffler was knocked loose and the rear bumper fascia was no longer attached to the vehicle. The CDC for this impact was 00UDDW2.

Figure 11. Undercarriage damage

The Avalon sustained moderate front end damage as a result of the impact with the utility pole. The vehicle sustained 38.0 cm (15.0 in) of direct damage along the front bumper, beginning 54.0 cm (21.3 in) right of the left front bumper corner, extending to the right. The right front tire was restricted and the right wheelbase was shortened

by 5.0 cm (2.0 in). The left wheelbase was lengthened by 2.0 cm (0.8 in). The bumper cover and energy absorbing styrofoam were no longer attached to the vehicle. An exemplar vehicle was located and measured so that the appropriate freespace could be subtracted from the front crush profile. Six crush measurements were documented along the front bumper as follows: C1=0.0 cm (0.0 in), C2=17.0 cm (6.7 in), C3=43.0 cm (16.9 in), C4=55.0 cm (21.7 in), C5=51.0 cm (20.1 in), C6=18.0 cm (7.1 in). The location of maximum crush was C4. The CDC for this impact was 12FZEN3.

Figure 12. Front crush profile

CDC (Impact 1):	12RZES1	
(Impact 2):	00UDDW2	
(Impact 3):	12FLMS6	
(Impact 4):	12FZEN3	
Delta V (Impact 4):	Barrier Equivalent speed	39.0 km/h (24.2 mph)

Figure 13. Exemplar vehicle's front bumper

Interior Damage - 2005 Toyota Avalon

The 2005 Toyota Avalon sustained moderate interior damage due to intrusion, occupant contacts and normal air bag deployment related damage.

The driver's seat belt retractor pretensioner actuated during the impact between the case vehicle and the utility pole and was locked in place post-crash. The seat belt was being worn by the driver and showed signs of occupant loading near the D ring. There was a red transfer found on the shoulder portion of the driver's seat belt.

There was integrity loss to the passenger compartment. The windshield was out-of-place and holed from impact forces. At the inspection, parts of the windshield were laying on the instrument panel and other sections were found in the front and second rows of the passenger compartment. None of the other glazing was damaged and showed no sign of occupant contact. The Avalon's four doors remained closed and operational.

The rearview mirror was no longer attached to the windshield and the roof mounted light panel was out of position. There was a small amount of blood found on the front of the deployed driver's front air bag. The blood likely came from a nose laceration the driver sustained during the crash.

Figure 14. Windshield damage - left side

Figure 15. Windshield damage - right side

Figure 16. Transfer to the driver's seat belt

There was longitudinal intrusion of the left instrument panel into the passenger compartment. The specific passenger compartment intrusion was documented as follows:

Figure 17. Roof mounted light and rearview mirror displaced

Row/Position	Intruded Component	Magnitude of Intrusion	Direction
1L	Instrument Panel	10.0 cm (3.9 in)	Longitudinal

Figure 18. Instrument panel damage/intrusion & shear module separation

Figure 19. Exemplar vehicle's instrument panel

Manual Restraint Systems - 2005 Toyota Avalon

The 2005 Toyota Avalon was configured with manual 3-point lap and shoulder belts for each of the five seating positions. Both front seat belts were equipped with B-pillar pretensioners and anchorage adjustments that were set to the full down position. The driver's belt pretensioner actuated during the collision with the utility pole and was locked in place post-crash. All five of the Avalon's seat belts were configured with sliding latch plates. The driver's safety belt had an emergency locking retractor (ELR). The remaining four seat belts had switchable ELR/automatic locking retractors.

Figure 20. Evidence of loading to driver's seat belt

The driver's seat belt showed obvious signs of occupant loading near the D ring and there was a red transfer found on the driver's shoulder belt. The source of the transfer is not known. The driver reported that he was wearing a white T-shirt and shorts on the day of the crash.

Supplemental Restraint Systems - 2005 Toyota Avalon

The Toyota Avalon was equipped with advanced occupant protection systems. These systems include the driver and front right passenger front air bags, driver knee air bag, front row seat back mounted side air bags and right/left side curtains.

Figure 21. Deployed driver's front air bag

As a result of the longitudinal deceleration of the Avalon during the impact with the utility pole, the driver's front and knee air bags deployed and the driver's seat belt retractor pretensioner actuated.

The driver's air bag deployed from the center of the steering wheel hub through H-configuration cover flaps. Both cover flaps measured 15.0 cm (5.9 in) in width and 7.0 cm (2.8 in) in height. The deployed driver air bag measured 58.0 cm (22.8 in) in diameter in its deflated state and the center stitching had a diameter of 29.0 cm (11.4 in). The air bag was tethered by a single internal strap and there were two vent ports located at the 12 o'clock position on the rear of the air bag. There was a small amount of blood on the front of the air bag, which was likely from a nose laceration the driver sustained during the crash. There was no damage or occupant contact visible to the cover flaps.

Figure 22. Deployed driver's knee air bag

The driver's knee air bag was mounted below the steering column. The air bag module had an H configuration. Both cover flaps measured 29.0 cm (11.4 in) in width. The top flap measured 5.0 cm (2.0 in) high, the bottom flap measured 6.0 cm (2.4 in) high. The air bag was semi-rectangular in shape. The top section of the bag measured 30.0 cm (11.8 in) wide. The bottom section was 54.0 cm (21.3 in) wide. The height of the bag was 28.0 cm (11.0 in). There was a piece of fabric made of the same material as the air bag that was sewn onto the lower right section of the bag and measured 20.0 cm (7.9 in) wide by 12.0 cm (4.7 in) high. The knee air bag did not have tethers or vent ports. The knee air bag and cover flaps showed no signs of damage or occupant contact.

The front right passenger air bag was a top instrument mount. The seat was equipped with an occupant sensor in the seat back. The front right seating position was not occupied, therefore the system did not warrant the deployment of the front right air bag. The Avalon was also equipped with dual front seat back mounted side air bags and front/rear side curtains. The side air bags and curtains did not deploy during the crash sequence.

Occupant Demographics - 2005 Toyota Avalon

	Driver
Age/Sex:	46/Male
Seated Position:	Front left
Seat Type:	Leather covered bucket seat
Height:	188 cm (74 in)
Weight:	100 kg (220 lb)
Occupation:	General maintenance contractor
Pre-existing Medical Condition:	Past head injury - NFS Past seizure disorder Fracture, thoracic spine - T1, chronic condition
Alcohol/Drug Involvement:	No drugs or alcohol (per medical records)
Driving Experience:	30 years
Body Posture:	Sitting upright, forward facing
Hand Position:	Believed to be on steering wheel. Right hand on the 2 o'clock position. Left hand on the 10 o'clock position.
Foot Position:	Right foot on accelerator. Left foot on floorboards.
Restraint Usage:	Manual 3-point lap and shoulder belt available - used (worn properly)
Air bag:	Front air bag available - deployed. Knee air bag available - deployed. Seat back mounted side air bag - nondeployed. Side curtain available - nondeployed.

Occupant Injuries - 2005 Toyota Avalon

Driver: Injuries obtained from Emergency Room records, radiological records, post-ER records, discharge records and driver interview.

Injury	OIC Code	Injury Mechanism	Confidence Level
Awake on admission, unconsciousness known to be less than 1 hour	160414.2,0	Unknown	Unknown
Cerebral Concussion	161000.2,0	Impact forces	Possible
Multiple abrasions, lower extremity, left	890202.1,2	Instrument panel	Possible
Fracture, displaced, lumbar spine, L1	650616.2,8	Impact forces	Possible
Abrasion, chest, upper left	490202.1,2	Seat belt webbing	Probable

Occupant Kinematics - 2005 Toyota Avalon

Driver Kinematics

The 46-year-old male driver [188 cm (74 in)/100 kg (220 lb)] was seated in the left front leather covered bucket seat and was restrained by the available 3-point manual lap and shoulder belt. The seat belt anchorage adjustment was set to the full down position. The seat track was adjusted 44.0 cm (17.3 in) aft of the bottom of the left A pillar. Based on measurements taken from an exemplar vehicle, the driver's seat track was set to the rearward most track position. The seat back was reclined at a 70 degree angle and the seat bottom had a 9.6 degree angle.

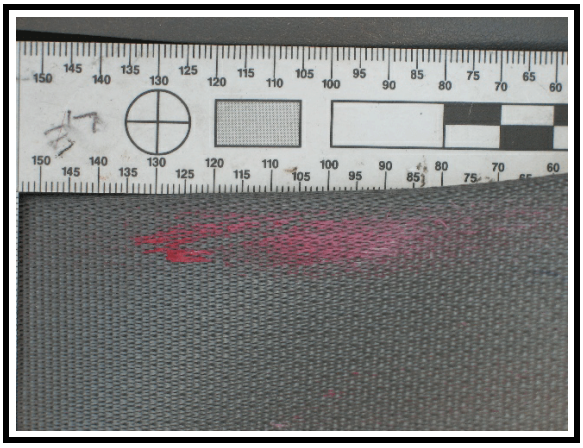

Figure 23. Close-up of transfer to driver's seat belt

The driver reported that approximately 0.40 km (0.25 m) before the intersection he had an episode and either fell asleep or suffered a hallucination. It is also possible that the driver may have suffered a seizure. He has a past history of seizures, although he reported that he has not had a problem with them in the last few years. He reported that during this episode, his right foot pressed down hard on the gas pedal, causing the Avalon to quickly accelerate. The vehicle traveled through the intersection and off the south roadway edge where it struck a lightweight wire fence. The driver estimated his pre-

crash and impact speeds as 129 km/h (80 mph). The fence impact was a low delta V event and the driver likely remained within his general seating area. The case vehicle continued south and traveled up a sloped dirt and sand median, causing the vehicle to become airborne. The driver reported that he believes his vehicle was at least 3 - 4.6 m (10 - 15 ft) off the ground. The Avalon landed on the adjacent highway, causing minor undercarriage damage. This non-horizontal crash event may have been the source of the driver's L1 compression fracture. The vehicle continued traveling south and struck another wire fence with its front end. During this low delta V impact, the driver likely remained within his general seating area. The vehicle continued southbound, and traveled over the second frontage road. The Avalon traveled over more sand and dirt and struck a utility pole with its front end, resulting in the deployment of the driver's front and knee air bags and the actuation of the driver's seat belt pretensioner. During this impact, the driver initiated a forward trajectory towards the 12 o'clock direction of force, loading his seat belt and likely contacting the deploying driver front air bag with his face. The driver was wearing safety glasses and it is likely that the glasses caused a laceration to the bridge of his nose when his face contacted the deploying driver front air bag. After the crash, the glasses were no longer on his face and were damaged. During the pole impact, it is also likely that this driver's lower legs contacted the deploying driver knee air bag, although no visible occupant contact evidence was found. After striking the pole, the vehicle rotated clockwise and came to final rest, facing northwest on the side of the roadway, near the pole.

The driver was conscious when police arrived and he reported that he was able to exit the vehicle on his own. He was transported by ambulance to an area trauma center where he was hospitalized for three days. According to the medical records, he sustained a cerebral concussion, an L1 compression fracture and abrasions to his upper left chest and lower left leg. The driver reported that he was bruised on his left collarbone, his chest and across his lower abdomen, which were likely from his manual 3-point lap and shoulder belt.

Attachment 1. Scene Diagram