INDIANA UNIVERSITY

TRANSPORTATION RESEARCH CENTER

School of Public and Environmental Affairs
222West Second Street
Bloomington, Indiana 47403-1501
(812) 855-3908 Fax: (812) 855-3537

ON-SITE AIR BAG INVESTIGATION

CASE NUMBER - IN97-017
LOCATION - INDIANA
VEHICLE - 1992 FORD TAURUS GL
CRASH DATE - June, 1997

Submitted:

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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.

Technical Report Documentation Page

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15. *Supplementary Notes*
On-site air bag deployment investigation involving a 1992 Ford Taurus GL, 4-door station wagon, with manual safety belts and dual front air bags, a 1991 Chevrolet Lumina, 4-door sedan, and a 1994 GMC Suburban, 4-door sport utility

16. *Abstract*

This report covers an on-site investigation of an air bag deployment crash that involved a 1992 Ford Taurus (Case Vehicle), a 1991 Chevrolet Lumina (vehicle #2), and a 1994 GMC Suburban (vehicle #3). This crash is of special interest because the case vehicle's restrained, front center passenger (4-year-old male) sustained a cervical fracture/dislocation fromcontacting the deploying driver air bag. In addition, the case vehicle's restrained driver (30-year-old female) was five-months pregnant and sustained only minor soft tissue injuries from her deploying air bag. The case vehicle was traveling east in the eastbound lane of a two-lane, undivided, county roadway. Vehicle #2 had been traveling west in the westbound lane of the same roadway and was turning left at the offset, four-leg intersection. Vehicle #3 was stopped heading north-northeast on the south leg of the intersection. The crash occurred in the four-leg, offset intersection. The front left corner of the case vehicle impacted the front left of vehicle #2, causing the case vehicle's driver (only) supplemental restraint (air bag) to deploy. The case vehicle was redirected to the right where the right side end swiped the front of vehicle #3 and the front right struck a SPEED LIMIT sign on the east roadside prior to coming to rest. The case vehicle's front center passenger was seated upright with his seat track located between its middle and rearmost positions. He was restrained by his available, manual, two-point, lap belt and sustained, according to his medical records, moderate injuries which included: a fracture of the body of C_2, a subluxation between C_2 and C_3, a large abrasion and contusion to the left side of his face, a laceration to his left earlobe, and abrasions and contusions to his left forehead and left orbital area. The driver was seated with her seat track located near the forward-most position, and her tilt steering wheel was located in its down-most position. She was restrained by her available, active, three-point, lap and shoulder belt and sustained, according to her interview, minor soft tissue injuries to her upper chest and right wrist. In addition she sustained a seat belt contusion to her superior abdomen and was checked for a fetal heartbeat prior to being released. The front right passenger (26-year-old male) was seated with his seat track located between its middle and rearmost positions and was restrained by his available, active, three-point, lap and shoulder belt. He did not sustain any injuries as a result of this crash.

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This on-site investigation was brought to NHTSA's attention on June 19, 1997 by NHTSA's Region V office. This crash involved a 1992 Ford Taurus GL (case vehicle), a 1991 Chevrolet Lumina (vehicle #2), a 1994 GMC Suburban (vehicle #3). The crash occurred in June 1997, at 1:49 p.m., in Indiana and was investigated by the applicable county sheriff department. This crash is of special interest because the case vehicle's restrained, front center passenger (4-year-old male) sustained a cervical fracture/dislocation from contacting the deploying driver air bag. It should also be noted that the case vehicle's restrained driver (30-year-old female) was five-months pregnant and sustained only minor soft tissue injuries from her deploying air bag. This contractor inspected the scene and vehicles on June 25, 1997. This contractor interviewed the case vehicle's driver on June 27, 1997. This report is based on the Police Crash Report, interviews with all three drivers, scene and vehicle inspections, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

SUMMARY

The case vehicle was traveling east in the eastbound lane of a two-lane, undivided, county roadway, intending to continue eastbound. Vehicle #2 had been traveling west in the westbound lane on the same, two-lane, undivided county roadway and was turning left intending to travel south on the south leg of the offset, four-leg intersection. Vehicle #3 was stopped heading north-northeast on the south leg of the intersection, waiting to turn right (i.e., a private driveway on the south side of the road). The case vehicle's driver made no avoidance maneuvers prior to the crash. The crash occurred in the driveway access portion of the four-leg offset intersection.

The front left corner of the case vehicle impacted the front left of vehicle #2, causing the case vehicle's driver (only) supplemental restraint (air bag) to deploy. The case vehicle was subsequently redirected approximately 15 degrees to the right (south) where the right side of the case vehicle end swiped the front of vehicle #3 and the front right of the case vehicle struck a SPEED LIMIT sign on the east roadside of the trafficway. The case vehicle continued eastward and came to rest heading east on the east shoulder approximately 26 meters (85 feet) farther east of the impacted SPEED LIMIT sign. Vehicle #2 rotated slightly counterclockwise and came to rest heading southwest straddling and diagonally across the centerline of the roadway. Vehicle #3 rotated slightly clockwise post-crash and came to rest heading north-northeast on the south leg of the intersection.

The case vehicle's driver [163 centimeters and 56 kilograms (64 inches, 123 pounds)] was restrained by her available, active, three-point, lap and shoulder belt. In addition, there was evidence of belt pattern bruising to the driver's upper abdomen, and the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of loading.

The front center passenger [92 centimeters and 18 kilograms (36 inches, 40 pounds)] was also restrained by his available, active, two-point, lap belt. An inspection of the front center passenger's seat belt webbing and latch plate showed no conclusive evidence of loading, but there was blood evidence on the webbing near the latch plate where this occupant would have had the seat belt latched as well as heavier than normal wear marks on the latch plate's webbing guides.

The case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of their available safety belts, the driver's and front center passenger's pre-impact body positions did not change just prior to impact. The case vehicle's primary impact with vehicle #2 deployed the driver's air bag, but the deployment was late in the crash sequence. The air bag did not deployed during the initial, narrow vehicle-to-vehicle interaction, but rather, it deployed when the case vehicle's left front wheel was snagged by vehicle #2, causing the case vehicle's wheelbase to be shortened by 19 centimeters (7.5 inches). Based on the vehicle inspection and occupant kinematic principles, the left front wheel's snagging action enabled all three front seat passengers to move forward and leftward towards the 11 o'clock (-20 degrees) direction of principal force (PDOF). As the small stature front center passenger continued forward, the lap belt held him at the waist, keeping him from contacting the steering wheel and/or column, the left/center dash, and possibly the windshield; however, the use of the lap belt allowed the front center passenger's head and upper torso to jackknife over the lap belt. The deploying driver air bag struck the driver in the upper right chest and the front center passenger on the left side of his face and neck between the 2 and 3 o'clock portion of the air bag. According to the front right passenger, immediately prior to the crash, he put his left arm across the front center passenger's chest, attempting to hold him back but to no avail. Upon impacting the deployed air bag, both the driver and front center passenger were driven backwards (i.e., the driver into her seat back and the front center passenger into the folded-up right front passenger's arm rest which acted as his seat back). The case vehicle's sideswipe impact with vehicle #3 most likely sent all three front seat occupants slightly to the right, toward the +10 degree PDOF, and forward as the case vehicle end swiped vehicle #3's front with its right side. The case vehicle's impact with the SPEED LIMIT sign had essentially no affect on any of the front seat occupants movement within the vehicle. The fact that all three front seat occupants were restrained by their belt restraints kept them from striking the case vehicle's windshield or dash. At final rest the front center passenger was slumped forward over his lap belt with his face almost touching the seat cushion.

The driver was transported by ambulance to the hospital. She was treated for minor soft tissue injuries to her right wrist/forearm, upper abdomen, and upper right chest and checked for a fetal heartbeat before being released. The front center occupant was transported by ambulance to the hospital. He was stabilized at the initial facility and then transferred to a trauma facility and hospitalized for 11 days post-crash. According to the front center passenger's medical records, he sustained: a fracture of the body of C_2, a subluxation between C_2 and C_3, a large abrasion and contusion to the left side of his face, a laceration to his left earlobe, and abrasions and contusions to his left forehead and left orbital area.

The case vehicle was a front wheel drive 1992 Ford Taurus, four-door station wagon (VIN: 1FACP57U5NG------). The case vehicle was not equipped with anti-lock brakes. Vehicle #2 is a front wheel drive 1991 Chevrolet Lumina, four-door sedan (VIN: 2G1WL54T9M1------). Vehicle #3 was a four wheel drive 1994 GMC Suburban, four-door sport utility (VIN: 1GKFK16K7RJ------). The case vehicle and vehicle #2 were both towed due to damage; vehicle #3 was driven from the scene. The CDC's for the case vehicle were determined to be: **11-FLEE-6 (-20)**, **12-RZES-1 (+10)**, and **12-FREE-1 (+360)**. For the deployment impact, maximum crush was 185 centimeters (72.8 inches) down the left side, and the direct damage width to the front bumper was 19 centimeters (7.5 inches). The CDC was determined to be: **11-FLEW-1 (+30),** for vehicle #2 [maximum crush was 13 centimeters (5.2 inches)], and **09-FYLS-1 (-90)**, for vehicle #3 [no measurable deformation]. No reconstruction program

was used on this crash because neither the case vehicle nor vehicle #2 reached a common velocity due to the impact configuration; however, this contractor's visually estimated Delta V is between 16 km.p.h. (10 m.p.h.) and 24 km.p.h. (15 m.p.h.).

The case vehicle's driver air bag was located in the steering wheel hub. An inspection of the air bag module's cover flaps and air bag revealed that the cover flaps opened at their designated tear points, and there was no evidence of damage during the deployment to the air bag or the cover flaps. In addition, there was no evidence of contact on the driver air bag module's cover flaps. The driver's air bag was designed with two tethers, 5 centimeters (2.0 inches). The driver's air bag had two vent ports, approximately 2.5 centimeters (1.0 inch) in diameter, located at the 11 and 1 o'clock positions. The deployed driver's air bag was round with diameter 67 centimeters (26.4 inches). There were two areas of interest on the driver's air bag: a blood drop at the 12 o'clock position and an area 15 by 10 centimeters (5.9 by 3.9 inches) of what appeared to be skin tissue and blood. The blood and skin deposit came from the front center occupant and were located at the 2 to 3 o'clock portion of the air bag's fabric. In addition, there was possible skin flakes present on the driver's sun visor.

Immediately prior to the crash the case vehicle's properly restrained driver was seated upright with her back against the seat back, her left foot on the floor, her right foot releasing the accelerator pedal, and both hands on the steering wheel--at the 10 and 2 o'clock positions. The seat track was near the forward-most position, and her tilt steering wheel was located in its down-most position. The distance from the center of the steering wheel hub to the center of the driver's seat back was 55 centimeters (21.7 inches).

The case vehicle's restrained front center passenger was seated upright with his back partially against the front right passenger's folded-up left arm rest and seat back, his feet hanging over the seat cushion, and both hands on his lap. The front seat is a 60/40 split bench with separate back cushions and driver and front right passenger arm rests that fold-up to form a seat back for the front center passenger. The seat track, for the seat in which the front center passenger was located, was between its middle and rearmost positions, and the seat back was upright.

The case vehicle's front right passenger [26-year-old, White (non-Hispanic) male] was seated in an upright posture with his back against the seat back, both feet on the floor, his left hand/arm on his lap (until just prior to the crash when he tried to hold the front center passenger back), and his right hand/arm on the right side armrest. The seat track for the 60 portion of the front 60/40 bench seat was located between its middle and rearmost positions and the seat back was upright. The case vehicle's front right passenger [185 centimeters and 95 kilograms (73 inches, 210 pounds)] was restrained by his available, active, three-point, lap and shoulder belt. An inspection of the front right passenger's seat belt webbing and latch plate showed no evidence of loading, and he had no safety belt-related injuries. The front right passenger was not transported to any medical facility, and he did not sustain any injuries as a result of this crash.

The driver of vehicle #2 was transported by ambulance from the scene to a hospital where she was treated and released with minor injuries. The driver of vehicle #3 did not sustain any injuries and was able to drive from the scene.

The case vehicle was traveling east in the eastbound lane of a two-lane, undivided, county roadway (**Figure 1**), intending to continue eastbound. Vehicle #2 had been traveling west in the westbound lane on the same, two-lane, undivided county roadway and was turning left intending to travel south on the south leg of the offset, four-leg intersection. Vehicle #3 was stopped heading north-northeast on the south leg of the intersection, waiting to turn right (i.e., a private commercial driveway on the south side of the road). All three vehicle's were traveling on a dry, bituminous roadway that was straight and level at the area of impact. The width of the travel lanes for the case vehicle and vehicle #2 were 3.9 meters (12.9 feet) and 4.1 meters (13.5 feet), respectively. The east and westbound lanes were divided by a dashed yellow line with white fog lines along the roadway edges. The roadway is bordered by gravel shoulders which measure 1 meter (3.3 feet). There were no controls other than a posted regulator SPEED LIMIT sign. The legal limit for the case vehicle was 80 km.p.h. (50 m.p.h.), transitioning to 72 km.p.h. (45 m.p.h.). The legal speed limit for vehicle #2 was 72 km.p.h. (45 m.p.h.). The estimated coefficient of friction for the roadway is 0.75%. The surrounding area is primarily residential with some farm land. The case vehicle's driver made no avoidance maneuvers prior to the crash. The crash occurred in the driveway access portion of the four-leg offset intersection.

The front left corner (**Figures 2** and **3**) of the case vehicle impacted the front left (**Figure 4** below) of vehicle #2, causing the case vehicle's driver (only) supplemental restraint (air bag) to deploy. The case vehicle was subsequently redirected approximately 15 degrees to the right (south) where the right side of the case vehicle end swiped the front of vehicle #3 and the

Figure 1: Case vehicle's approach path in eastbound lane to offset four-leg intersection showing approx-imate point of impact (red cone); Note: vehicle #2 was approaching from the background in the west-bound lane and vehicle #3 was stopped on the south (toward right) leg (case photo #02)

Figure 2: Case vehicle's front left corner damage from impact with vehicle #2; Note: damage extends down left side to driver's door, and vertical yellow tape indicates direct damage length (case photo #20)

Figure 3: Close-up of direct damage width to case vehicle's front left bumper corner (case photo #23)

front right of the case vehicle struck a SPEED LIMIT sign on the east roadside of the trafficway. The case vehicle continued eastward (**Figure 5**) and came to rest heading east on the east shoulder approximately 26 meters (85 feet) farther east of the impacted SPEED LIMIT sign. Vehicle #2 rotated slightly counterclockwise and came to rest heading southwest straddling and diagonally across the centerline of the roadway. Vehicle #3 rotated slightly clockwise post-crash and came to rest heading north-northeast on the south leg of the intersection (**Figures 6** through **8**).

Figure 4: On-scene view of vehicle #2 at final rest showing crush to front left (case photo #54A)

Figure 5: Case vehicle's path of travel after impacting vehicles #2 and #3 showing scuff marks from left front tire (highlighted by arrows) and replaced SPEED LIMIT sign struck before coming to rest (case photo #05)

Figure 6: Final rest positions showing case vehicle in center background on south roadside, vehicle #2 at left after rotating counterclockwise, and vehicle #3 at right after rotating clockwise (case photo #17)

Figure 7: On-scene view of case vehicle at final rest; Note: vehicle #3 (Suburban) in background and struck speed limit sign directly behind case vehicle (case photo #15)

Figure 8: On-scene view of case vehicle's right side damage from end swipe with vehicle #3; Note: vehicle #2 at final rest in background (case photo #16)

The case vehicle was a front wheel drive 1992 Ford Taurus GL, six-passenger, four-door station wagon (VIN: 1FACP57U5NG------) equipped with a 3.0L, SEFI, V-6 engine, power-assisted rack and pinion steering, and a four-speed automatic transmission with overdrive. Braking was achieved by a power-assisted, four-wheel disc system; anti-lock brakes are an option for this model, but the case vehicle was not so equipped. The case vehicle's wheel base was 269 centimeters (106.0 inches), and the odometer reading at inspection was 136,777 kilometers (84,989 miles).

The front seat of the case vehicle was equipped with an adjustable split bench (60/40) with separate back cushions and adjustable head restraints. The split bench was equipped with center arm rests for the driver and front right passenger, and when folded up, these armrests formed the seat back for the front center seating position. The rear seat was a regular full bench seat. The case vehicle had manual, three-point, lap and shoulder belts in the four outboard seating positions and manual, two-point, lap belts in the front and rear center seating positions. The vehicle was equipped with a knee bolster on the driver's side which was not deformed. The case vehicle was not equipped with manually operated height adjusters for the "D"-rings. Automatic restraint was provided by a Supplemental Restraint System (SRS) that consisted of a frontal air bag for the driver. An examination of the interior revealed evidence of air bag exhaust to the driver's sun visor header area and possibly to the left corner of the front right passenger's sun visor.

CASE VEHICLE DAMAGE

The initial contact involved the front left bumper corner (**Figures 2** above) of the case vehicle against the front left bumper of vehicle #2 (**Figure 4** above). The direct contact damage consisted of a longitudinal abrasive pattern that began 54 centimeters (21.3 inches) left of the center and extended 19 centimeters (7.5 inches) to the front left bumper corner (**Figure 3** above). The corner impact was primarily a narrow end engagement that continued down the left side of the case vehicle snagging the left front wheel. The snagging action separated the left lower ball joint from the steering spindle and displaced the left lower control arm rearwards; in addition, the snagging deployed the case vehicle's driver air bag. The residual deformation to the bumper reinforcement bar was nonexistent except for scratches and abrading to the bumper fascia. Direct damage continued down the left side a distance of 185 centimeters (72.8 inches) and ended just past the left "A"-pillar. The left fender, hood, bumper fascia, left wheel assembly, and left front door were deformed. The case vehicle's left front tire was deflated or physically restricted. There was no evidence of intrusion to the case vehicle's interior.

Figure 9: Sideswipe damage to case vehicle's right side from vehicle #3's front left bumper corner (case photo #27)

The case vehicle's right side impact with vehicle #3 began on the right front door (**Figure 9**), and the sideswiping type damage extended to the right quarter panel. The direct damage length was 205 centimeters (80.7 inches). The right front door, right rear door, and right quarter panel were deformed; maximum crush was 5 centimeters (2.0 inches) and occurred to

the right rear door panel. The case vehicle's front right impact with the regulatory SPEED LIMIT sign (**Figure 10**) resulted in 19 centimeters (7.5 inches) of direct damage (i.e., scrapes and scratches) along the front right bumper.

The CDC's for the case vehicle were determined to be: **11-FLEE-6 (-20)** for the impact with vehicle #2, **12-RZES-1 (+10)** for the impact with vehicle #3, and **12-FREE-1 (+360)** for the impact with the regulatory sign. For the deployment impact, maximum crush was 185 centimeters (72.8 inches) down the left side, and the direct damage width to the front bumper was 19 centimeters (7.5 inches). No reconstruction program was used on this crash because neither the case vehicle nor vehicle #2 reached a common velocity due to the impact configuration; however, this contractor's visually estimated Delta V is between 16 km.p.h. (10 m.p.h.) and 24 km.p.h. (15 m.p.h.). The case vehicle was towed due to damage.

Figure 10: Scraping to the case vehicle's front right bumper corner from contacting regulatory SPEED LIMIT sign (3RD event) prior to coming to rest (case photo #30)

AUTOMATIC RESTRAINT SYSTEM

As previously mentioned, the case vehicle was equipped with a SRS that consisted of a frontal air bag at the driver position. The SRS deployed as a result of the case vehicle's frontal impact with the front left of vehicle #2. The case vehicle's driver air bag was located in the steering wheel hub (**Figure 11**). The module cover consisted of asymmetrical cover flaps with overall dimensions of 20.5 centimeters (8.1 inches) along the horizontal seam and vertical heights of 14 centimeters (5.5 inches) for the upper flap and 4 centimeters (1.6 inches) for the lower flap. The driver's air bag was designed with two tethers, each 5 centimeters (2.0 inches) wide and sewn to the interior center face of the air bag. The driver's air bag had two vent ports, approximately 2.5 centimeters (1.0 inch) in diameter, located at the 11 and 1 o'clock positions. The deployed driver's air bag was round with a diameter of 67 centimeters (26.4 inches).

Figure 11: Deformation to top of case vehicle's steer-ing wheel rim which resulted when the driver loaded the deploying air bag causing the air bag to expand backwards into the rim; Note: steering wheel inverted (case photo #34)

An inspection of the air bag module's cover flaps and air bag revealed that the cover flaps opened

at their designated tear points and that the bottom flap was blown through the spokes of the steering wheel rim. However, there was no evidence of damage during the deployment to the air bag or the cover flaps. In addition, there was no visible evidence of direct contact on the driver air bag module's cover flaps from the driver or front center passenger. An inspection of the case vehicle's tethered, driver air bag revealed two areas of interest. First, there was a blood spot towards the center of the air bag (12 o'clock position), 14 centimeters (5.5 inches) down from the top edge and 2 centimeters (0.8 inches) in width. Second, there was an area: 15 by 10 centimeters (5.9 by 3.9 inches), of what appeared to be skin tissue and blood (**Figure 12**). This contact area extended inwards from the right outside edge 10 centimeters (3.9 inches) and was 15 centimeters (5.9 inches) in length. The blood and skin deposit came from the front center occupant and were located at the 2 to 3 o'clock portion of the air bag's fabric (**Figure 13**). The angled distance was measured from the steering wheel hub to the center of the vertically positioned driver's arm rest (**Figure 14**), against which the front center passenger was leaning. The measured distance was approximately 48 centimeters (18.9 inches).

Figure 12: Case vehicle's driver air bag with steering wheel in upright position; Note: yellow tape high-lights area of contact (i.e., skin transfer) by front center passenger (case photo #37)

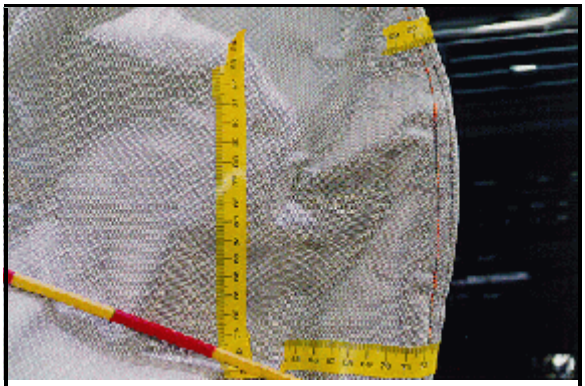


Figure 13: Close-up of skin transfer to right side of case vehicle's driver air bag from contact with the left side of the front center passenger's face (case photo #38)

CASE VEHICLE FRONT CENTER PASSENGER KINEMATICS

The case vehicle's front center passenger [4-year-old, White (non-Hispanic) male] was restrained by his available, active, two-point, lap belt. An inspection of the front center passenger's seat belt webbing and latch plate showed no conclusive evidence of loading, but there was blood evidence on the webbing near the latch plate (**Figure 15** below) where this occupant would have had the seat belt latched as well as heavier than normal wear marks on the latch plate's webbing guides.

Figure 14: Case vehicle's front seating area; Note: difference in seat track placement between driver and passenger seats, and ceiling tape indicates air bag exhaust residue (case photo #50)

The front center passenger [92 centimeters and 18 kilograms (36 inches, 40 pounds)] was seated upright with his back partially against the front right passenger's folded-up left arm rest and seat back, his legs outstretched in front of him with his feet hanging

off the front edge of the seat cushion, and both hands on his lap. The front seat is a 60/40 split bench with separate back cushions and driver and front right passenger arm rests that fold-up to form a seat back for the front center passenger. The seat track for the seat the front center passenger was in (i.e., 60% portion of the split bench), was located between its middle and rearmost positions, and the seat back was upright.

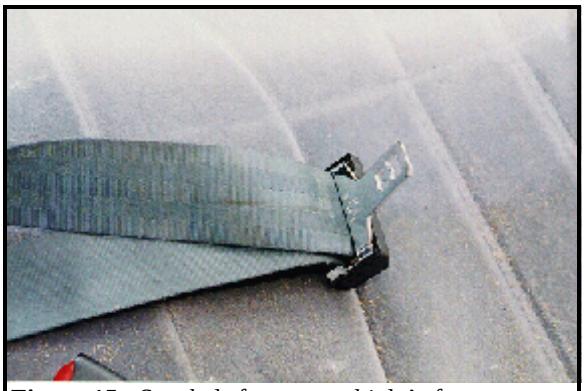


Figure 15: Seat belt for case vehicle's front center passenger showing blood streak on backside of belt webbing, near latch plate (case photo #48)

The case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of his available safety belt, the front center passenger's pre-impact body position did not change just prior to impact. The case vehicle's primary impact with vehicle #2, deployed the driver's air bag, but the deployment was late in the crash sequence. Rather the air bag deployed when the case vehicle's left front wheel was snagged by vehicle #2, shortening the case vehicle's wheelbase by 19 centimeters (7.5 inches). Based on the vehicle inspection and occupant kinematic principles, the left front wheel's snagging action enabled the front center passenger to continued forward and leftward towards the 11 o'clock (-20 degrees) direction of principal force (PDOF). As this small stature passenger continued forward the lap belt held him at the waist, keeping him from contacting the steering wheel and/or column, the left/center dash, and possibly the windshield; however, the use of the lap belt allowed the passenger's head and upper torso to jackknife over the lap belt. The deploying driver air bag struck the front center passenger on the left side of his face and neck between the 2 and 3 o'clock portion of the air bag. According to the front right passenger, immediately prior to the crash, he put his left arm across the front center passenger's chest, attempting to hold him back but to no avail. Upon impacting the deployed air bag, the front center passenger was driven back into the folded-up, front right seating position's left arm rest, which acted as the front center passenger's seat back. The case vehicle's sideswipe impact with vehicle #3 most likely sent the front center passenger slightly to the right, toward the +10 degree PDOF, and forward as the case vehicle end swiped vehicle #3's front with its right side. The case vehicle's impact with the SPEED LIMIT sign had essentially no affect on the front center occupant's movement within the vehicle. At final rest the front center passenger was still restrained in his seat and slumped forward over his lap belt with his face almost touching the seat cushion.

CASE VEHICLE FRONT CENTER PASSENGER INJURIES

The front center occupant was transported by ambulance to the hospital where he was treated and stabilized at the initial facility prior to being transferred by helicopter to a hospital with a pediatric neurologist and neurosurgeon and hospitalized for 11 days post-crash. According to the front center passenger's medical records, he sustained: a fracture of the body of C_2, a subluxation between C_2 and C_3, a large abrasion and contusion to the left side of his face, a laceration to his left earlobe, and abrasions and contusions to his left forehead and left orbital area. The **SELECTED PHOTOGRAPHS** section below shows photographs (**Figures 18** through **21** below) of the atlas, the axis (including the unique body of the axis), and their articulation.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Fracture (Type III[1]) of body of C_2 with 2 mm of anterior subluxation of C_2 relative to C_3 and disc space widening between C_1 & C_2 and C_2 & C_3 suggestive of ruptures of posterior longitudinal ligaments of C_2-C_3	650230.2 moderate	Air bag, driver's	Certain	Hospitalization records
2	Abrasions left periorbital area with edema	297202.1 minor	Air bag, driver's	Certain	Emergency room records
3	Contusion {ecchymosis} left periorbital area with edema	297402.1 minor	Air bag, driver's	Certain	Emergency room records
4	Abrasions left cheek	290202.1 minor	Air bag, driver's	Certain	Hospitalization records
5	Contusion {ecchymosis} left cheek	290402.1 minor	Air bag, driver's	Certain	Hospitalization records
6	Abrasions left forehead	290202.1 minor	Air bag, driver's	Certain	Emergency room records
7	Contusion left forehead	290402.1 minor	Air bag, driver's	Certain	EMS treatment record
8	Lacerations left ear (pinna)	290602.1 minor	Air bag, driver's	Probable	Hospitalization records

[1] See the section entitled: **C_2 FRACTURES: ODONTOID FRACTURES AND HANGMAN'S FRACTURES** below and specifically **Figure 22**.

The case vehicle's driver [30-year-old, White (non-Hispanic) female] was restrained by her available, active, three-point, lap and shoulder belt. In addition, there was evidence of belt pattern bruising to the driver's upper abdomen, and the inspection of the driver's seat belt webbing, "D"-ring, and latch plate showed evidence of loading (abrasion) to the plastic "D"-ring from the belt webbing.

The case vehicle's driver [163 centimeters and 56 kilograms (64 inches, 123 pounds)] was seated upright with her back against the seat back, her left foot on the floor, her right foot releasing the accelerator pedal, and both hands on the steering wheel--at the 10 and 2 o'clock positions. The seat track was near the forward-most position, and her tilt steering wheel was located in its down-most position. The distance from the center of the steering wheel hub to the center of the driver's seat back was 55 centimeters (21.7 inches). Considering the driver's close proximity to the steering wheel and the steering column being tilted in its down-most position, it is noteworthy that the driver did not sustain any injury to her unborn five month old fetus.

The case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of her available safety belts, the driver's pre-impact body position did not change just prior to impact. The case vehicle's primary impact with vehicle #2, deploy the driver's air bag, but the deployment was late in the crash sequence. Rather the air bag deployed when the case vehicle's left front wheel was snagged by vehicle #2, shortening the case vehicle's wheelbase by 19 centimeters (7.5 inches). The left front wheel's snagging action enabled the driver to continue forward and leftward towards the 11 o'clock (-20 degrees) direction of principal force (PDOF). The deploying driver air bag struck the driver in the upper right chest. There was no visible evidence of driver contact on the air bag. The driver's usage of her three-point safety belt, which locked-up, prevented her from more serious injury. There was no evidence of compression of the energy absorbing shear capsules in the base of the steering column; although, the top half of the steering wheel rim was deformed 3 centimeters (1.2 inches). The steering wheel rim was inverted at the time of the vehicle inspection due to the snagging of the left front wheel (**Figure 11** above). Upon impacting the deployed air bag, the driver rebounded back into her seat back. The case vehicle's sideswipe impact with vehicle #3 most likely sent the case vehicle's driver slightly to the right, toward the +10 degree PDOF, and forward as the case vehicle end swiped vehicle #3's front with its right side. The case vehicle's impact with the SPEED LIMIT sign had essentially no affect on the driver's movement within the vehicle. The fact that the driver was restrained by her belt restraints kept her from striking the case vehicle's steering wheel/column, dash, or windshield. As the case vehicle came to rest the driver remained in her seat.

CASE VEHICLE DRIVER INJURIES

The driver was transported by ambulance to the hospital. Based on the driver's interview, she was treated for minor soft tissue injuries to her right wrist/forearm and upper abdomen from the deploying air bag, and a contusion to her upper abdomen from her seat belt. The primary reason that the driver was transported and examined was the fact that she was five-months pregnant, and the rescue personnel insisted on the checking the fetal heartbeat before releasing her.

Injury Number	Injury Description (including Aspect)	NASS Injury Code & AIS 90	Injury Source (Mechanism)	Source Confidence	Source of Injury Data
1	Contusion {bruise} right upper chest	490402.1 minor	Air bag, driver's	Probable	Interviewee (same person)
2	Contusion {bruise} superior abdomen (above belly button), diagonally from left shoulder toward right hip	590402.1 minor	Safety belt, torso portion	Probable	Interviewee (same person)
3	Abrasions right wrist	790202.1 minor	Air bag, driver's	Probable	Interviewee (same person)

CASE VEHICLE FRONT RIGHT PASSENGER KINEMATICS

The case vehicle's front right passenger [26-year-old, White (non-Hispanic) male] was seated in an upright posture with his back against the seat back, both feet on the floor, his left hand/arm on his lap (until just prior to the crash when he tried to hold the front center passenger back), and his right hand/arm on the right side armrest. The seat track for the 60 portion of the front 60/40 bench seat was located between its middle and rearmost positions and the seat back was upright.

The case vehicle's front right passenger [185 centimeters and 95 kilograms (73 inches, 210 pounds)] was restrained by his available, active, three-point, lap and shoulder belt. An inspection of the front right passenger's seat belt webbing and latch plate showed no evidence of loading, and he had no safety belt-related injuries. In addition, there were no indications of contact with the dash. The front right passenger was not transported to any medical facility, and he did not sustain any injuries as a result of this crash.

The case vehicle's driver made no known pre-crash avoidance maneuvers. As a result and independent of the use of his available safety belts, the front right passenger's pre-impact body position did not change just prior to impact. The case vehicle's primary impact with vehicle #2, deployed the driver's air bag, but the deployment was late in the crash sequence. Rather the air bag deployed when the case vehicle's left front wheel was snagged by vehicle #2, shortening the case vehicle's wheelbase by 19 centimeters (7.5 inches). The left front wheel's snagging action enabled the front right passenger to move forward and leftward towards the 11 o'clock (-20 degrees) direction of principal force (PDOF). According to the front right passenger, immediately prior to the crash, he put his left arm across the front center passenger's chest, attempting to hold him back but to no avail. Upon loading his safety belts, front right passenger rebounded back into his seat back. The case vehicle's sideswipe impact with vehicle #3 most likely sent the front right occupant slightly to the right, toward the +10 degree PDOF, and forward as the case vehicle end swiped vehicle #3's front with its right side. The case vehicle's impact with the SPEED LIMIT sign had essentially no affect on the front right passenger's movement within the vehicle. The fact that the front right passenger was restrained by his belt restraints kept him from striking the case vehicle's windshield or center/right dash. As the case vehicle came to rest the front right passenger remained in his seat.

The front right passenger was not injured in the crash and received no treatment.

VEHICLE #2

Vehicle #2 is a front wheel drive 1991 Chevrolet Lumina, six-passenger, four-door sedan (VIN: 2G1WL54T9M1------) equipped with a 3.1L, MFI, V-6 engine and a four-speed automatic transmission. Anti-lock brakes are not an option for this model. vehicle #2's wheel base was 273 centimeters (107.5 inches), and the odometer reading at inspection was 146,511 kilometers (91,038 miles). The vehicle's front seating area had a split bench with separate back cushions and adjustable head restraints. The rear seat was a bench seat without head restraints. The front and rear outboard seats were equipped with manual, three-point, lap and shoulder belts, and manual, two-point, lap belts were installed in the front and rear center seating positions.

Vehicle #2's direct damage started 21 centimeters (8.3 inches) left of center and extended to the left front bumper corner. The left half of the grille and left headlight assembly were broken out. The bumper fascia was abraded with the bumper reinforcement bar deformed on the left corner only. The hood and left front fender were damaged as well. The CDC was determined to be: **11-FLEW-1 (+30)** [maximum crush was 13 centimeters (5.2 inches)]. No reconstruction program was used on this crash because neither the case vehicle nor vehicle #2 reached a common velocity due to the impact configuration. Vehicle #2 was towed due to damage.

The driver of vehicle #2 was transported by ambulance from the scene to a hospital where she was treated and released with minor injuries.

VEHICLE #3

Vehicle #3 was a four wheel drive 1994 GMC Suburban K-1500 (½ ton, 4x4), eight-passenger, four-door sport utility (VIN: 1GKFK16K7RJ) equipped with a 5.7L, FI/TBI, V-8 engine, and a four-speed automatic transmission. Four-wheel anti-lock brakes are standard for this model. Vehicle #3's wheel base was 334 centimeters (131.5 inches), and the odometer reading at inspection was 70,327 kilometers (43,699 miles). The vehicle was equipped with bucket seats and integral head restraints. The three outboard seats had manual, three-point, lap and shoulder belts with a lap belt in the second seat center position. The back seat was a split bench with folding backs for the rear cargo area.

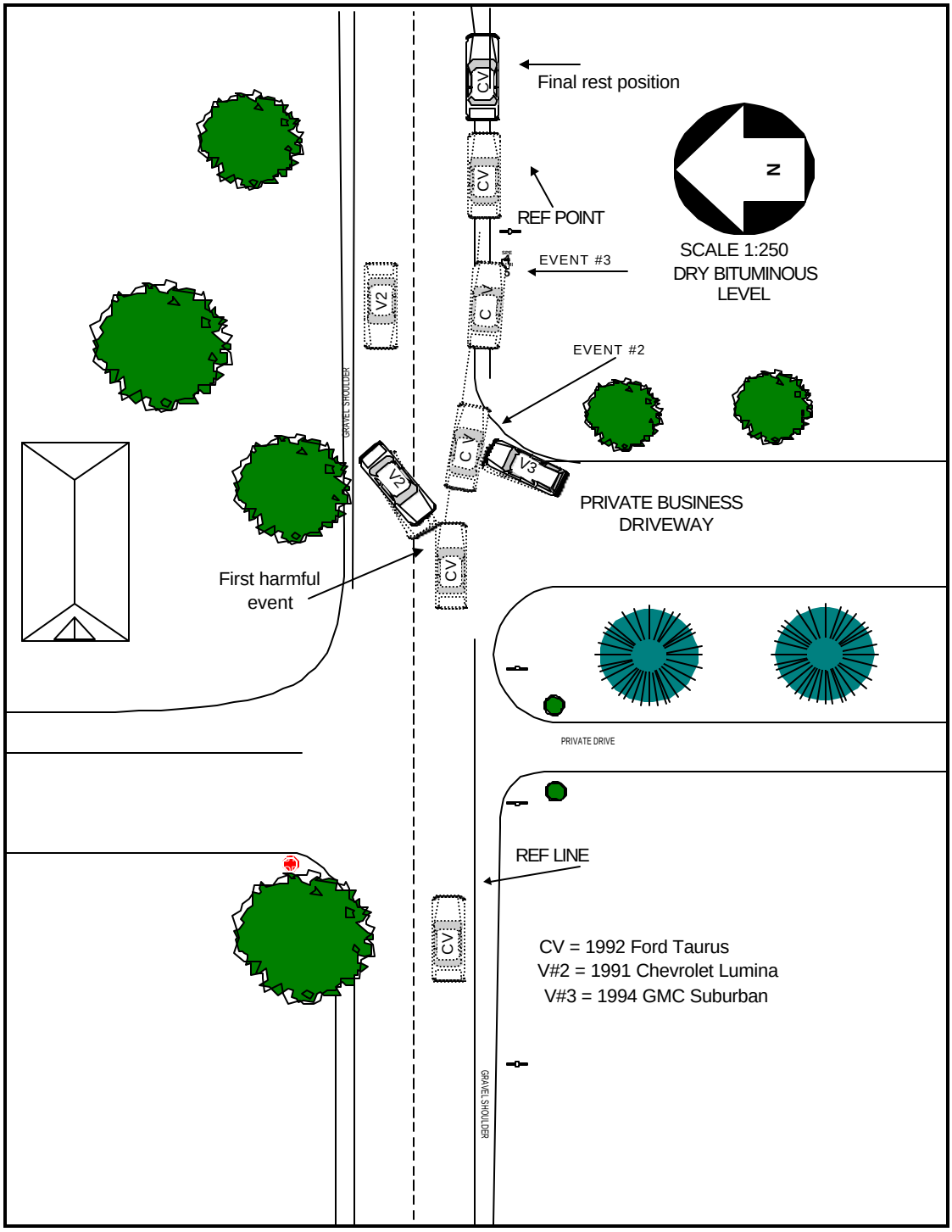
Figure 16: Vehicle #3's frontal damage viewed from left of front; Note: direct damage to front left bumper corner and missing bumper guard; also, tape indicates direct and induced damage (case photo #62)

Direct damage to vehicle #3's front bumper began 39 centimeters (15.4 inches) left of center and extended out to the left front bumper corner. The only damage to the bumper, besides abrading of the rubber bumper trim, involved the left bumper guard

being torn away during the end swiping type impact with the case vehicle (**Figure 16** above and **Figure 17**). The CDC was determined to be: **09-FYLS-1 (-90)** with no measurable deformation. Vehicle #3 was driven from the scene.

The driver of vehicle #3 did not sustain any injuries and was able to drive from the scene.

Figure 17: Close-up of end swipe damage to vehicle #3's front bumper; Note: missing front left bumper guard (case photo #62)


Final rest position
N
REF POINT
SCALE 1:250
DRY BITUMINOUS
LEVEL
EVENT #3
EVENT #2
GRAVEL SHOULDER
PRIVATE BUSINESS
DRIVEWAY
First harmful
event
PRIVATE DRIVE
REF LINE
GRAVEL SHOULDER
CV = 1992 Ford Taurus
V#2 = 1991 Chevrolet Lumina
V#3 = 1994 GMC Suburban

These photographs were taken from the book entitled: COLOR ATLAS OF HUMAN BODY, by McMinn, R.M.H., and R.T. Hutchings, Year Book Medical Publisher, Inc., Chicago, 1977.

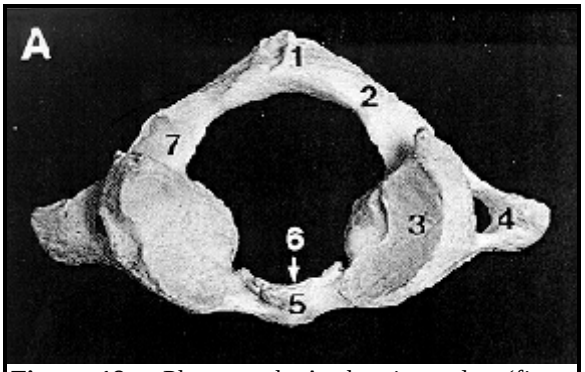


Figure 18: Photograph A showing atlas (first cervical vertebra) from above. The superior articular facets are concave and kidney-shaped. The ante-rior arch is straighter and shorter than the posterior arch and contains on its posterior surface the facet for the dens (odontoid) of the axis. The atlas is the only vertebra that has no body.

1. Posterior tubercle
2. Posterior arch
3. Lateral mass with superior articular facet
4. Transverse process and foramen
5. Anterior arch and tubercle
6. Facet for dens (odontoid) of axis
7. Groove for vertebral artery

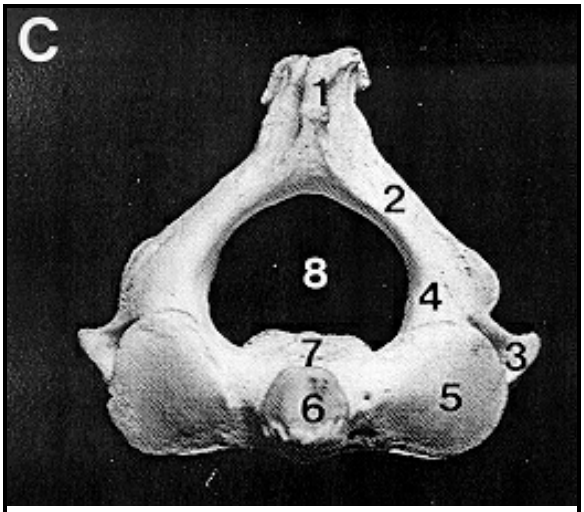


Figure 19: Photograph C showing the axis (second cervical vertebrae) from above. The axis is unique in having the dens (odontoid) which projects upwards from the body and represents the body of the atlas.

2. Lamina
3. Transverse process and foramen
4. Pedicle
5. Superior articular surface
6. Dens (odontoid)
7. Body
8. Vertebral foramen

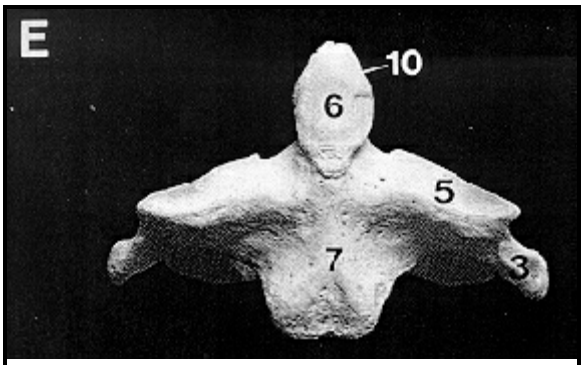


Figure 20: Photograph E showing the axis (second cervical vertebrae) from the front. The axis is unique in having the dens (odontoid) which projects upwards from the body and represents the body of the atlas.

3. Transverse process and foramen
5. Superior articular surface
6. Dens (odontoid)
7. Body
10. Impression for alar ligament

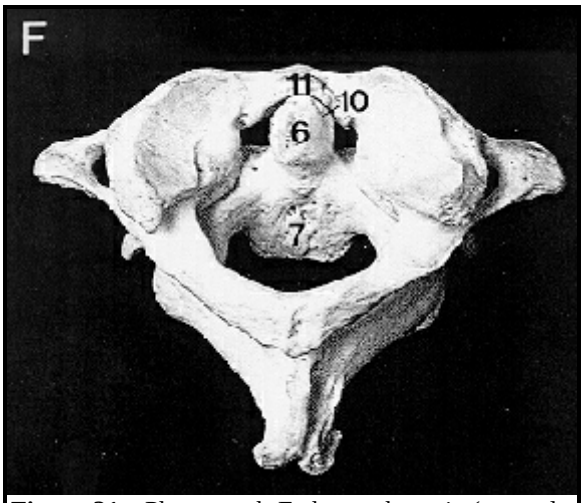


Figure 21: Photograph F shows the axis (second cervical vertebrae) articulated with the atlas (first cervical vertebrae) from above and behind. The axis is unique in having the dens (odontoid) which projects upwards from the body of the axis and represents the body of the atlas.

6. Dens (odontoid)
7. Body of axis (second cervical vertebrae)
10. Impression for alar ligament
11. Anterior arch of atlas (first cervical vertebrae)

The following figure and information was taken from Chapter 18: **SPINE**, written by Anderson, Paul A., from the book "**Orthopaedic Trauma Protocols**", edited by Hansen Jr., Sigvard T., and Swiontkowski, Marc F. of Harborview Medical Center; Raven Press, New York, 1993.

MECHANISMS OF INJURY: Fractures of the odontoid process occur in 7% to 10% of all cervical spinal injuries. The usual mechanism of injury is forced extension of the head and neck secondary to a fall or a collision (e.g., striking the head on the dashboard or windshield of an automobile in a motor vehicle accident. Associated fractures of the atlas occur in 10% to 15% of these cases. Fractures through the pars interarticularis of the axis are commonly called hangman's fractures because their pathology is similar to fractures caused by judicial hangings. The high frequency of associated facial trauma attests to the mechanism of injury, which is usually hyperextension of the neck. Because the size of the spinal canal is enlarged by this injury, neurologic deficits are rare.

ANATOMIC CONSIDERATIONS: The odontoid process projects from the body of C_2 and is narrowest at the waist, where it is most commonly fractured. The pars interarticularis of C_2 lies between the anteriorly placed superior articular facets and the posteriorly placed inferior facets. This small tubular bone can be easily fractured by forced extension. After fracture, the anterior longitudinal ligament, the C_{2-3} disc annulus, and the posterior longitudinal ligament are stressed and may progressively fail.

CLASSIFICATION: **Odontoid Fractures** -- Anderson and D'Alonzo based their classification of odontoid fractures on the location of the fracture (see Figure). **Hangman's Fractures** - Bucholz described hangman's fractures as stable or unstable injuries on the basis of the amount of C_2-C_3 discoligament injury associated with the fracture. Stable hangman's fractures are minimally displaced and the C_2-C_3 disc is intact. In unstable hangman's fractures, the C_2-C_3 disc is disrupted, resulting in C_2-C_3 vertebral body subluxation. A rare third type of hangman's fracture was identified by Levine and Edwards. This injury consists of fracture of the pars interarticularis and dislocation of the C_2-C_3 facet joints.

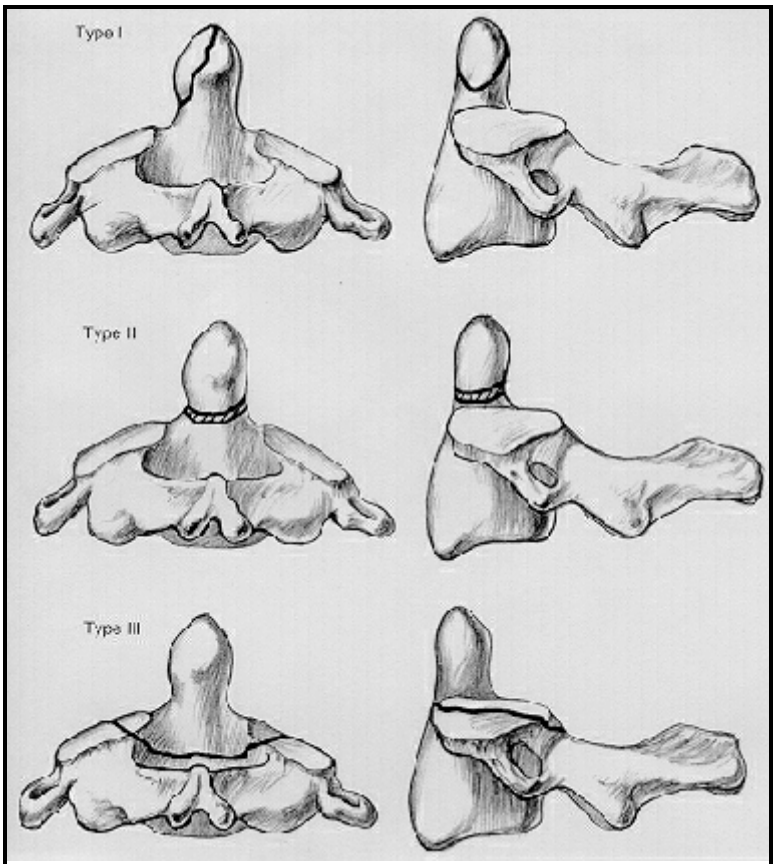


Figure 22: Anderson and D'Alonzo classification of odontoid fractures.
Type I: rare, stable avulsion fractures of the tip of the dens
Type II: unstable transverse fractures in the cortical bone of the waist of the dens
Type III: unstable fractures in the cancellous bone of the body of C_2