THE EFFECT OF MOTOR VEHICLE AIRBAG DEPLOYMENT ON TOOTH SURFACES

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ABSTRACT

Motor vehicle airbag technology is directed at the reduction of injury to drivers and passengers however a number of researchers have reported cases of injuries caused by airbags. Injuries to tooth surfaces, particularly tooth wear following the deployment of motor vehicle airbags, have never been studied. A review of the literature and clinical experience does not suggest tooth enamel abrasion to be a likely outcome following airbag deployment.

This *in vitro* pilot study was conducted to assess the effect on tooth surfaces following the deployment of motor vehicle airbags, and in particular to attempt to reproduce the injuries claimed in a case report published in the Journal of Forensic Odonto-Stomatology in December 2007. A sample of extracted upper anterior teeth (n = 20) were analyzed using unaided visual observation, photographic and microscopic observation pre- and post- airbag deployment. Teeth were mounted on a fabricated head form (similar to those used in crash test dummies) using dental putty. The tests were performed using a modified airbag test rig with airbags deployed in 5 different positions relative to the head, with respect to distance and angulations.

The result of the tests showed no changes to the teeth with unaided observation, macro photography or under the microscope. Tooth wear patterns described in the case report were not observed. Although accurate reproduction of an *in vivo* situation is not possible, this study has given some insight into the effects of motor vehicle airbag deployment, and suggests that significant tooth wear is an unlikely outcome from airbag deployment.
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Key Words: forensic odontology, airbag injury, tooth wear

INTRODUCTION

The airbag was first introduced as a safety feature in cars to reduce injuries to drivers following frontal collision.[1] A typical airbag system consists of three main components: an airbag module that houses the inflation system and the rubber-lined nylon bags, crash sensors and associated wiring harness that detect sudden deceleration of the vehicle and activates the deployment system of the air bag, and an electronic diagnostic unit that monitors the system's operation.[2] Driver airbags are installed at the centre of the steering wheel and their design depends in part on the governing design regulations. Airbag systems vary in the type and location of sensors, the chemicals used for inflation, the rate of inflation, construction and deployment conditions.[3,4] For example, in the USA, airbags are approximately 60 cm in diameter when fully deployed, with a volume of 70L.[3] However, in Europe, airbags are approximately 30L in volume.[3] Airbags inflate under high pressure in about 50ms.[3]

There are a number of case reports which have cited injuries due to the deployment of airbags during road traffic accidents.[5-15] Non fatal injuries range in severity from superficial abrasions to burns and bone fractures.[16] An article published in the Journal of Forensic Odonto-stomatology in December 2007 reported a case of tooth wear following a motor vehicle accident.[17] An adult male was involved in an offset frontal collision with an oncoming vehicle. Intraoral "injuries" in the reported case were described as buccal ring abrasions extending from the upper right lateral incisor (12) to the upper left second premolar (25). A review of the literature found no reports of injuries similar to those claimed in this case. Experience of dental wear observed clinically suggested that it is highly unlikely that the injuries are the result of airbag deployment.

This paper describes a study in which airbag laboratory test facilities were utilized to examine the effects of airbag deployment on teeth under controlled conditions. The aim of the study was to observe the possible occurrence of tooth wear during contact with a deploying airbag *in vitro.* The hypothesis is that there would be no changes to the tooth surfaces following the event.

MATERIALS AND METHODS

Ethical approval for the use of extracted human teeth was granted by the Human Research Ethics Committee, University of Adelaide and a convenient sample of 20 human upper anterior permanent teeth, extracted for clinical purposes, was collected. All teeth were treated with 10% Neutral Buffered Formalin by trained personnel in accordance to the Safe Operating Procedure for the safe use of extracted teeth guidelines provided by the School of Dentistry, University of Adelaide.

In order to ensure that pre-existing conditions such as tooth wear, fillings, caries or crack lines were well documented, all teeth were subjected to three levels of examination including unaided observation, photographic examination using a Nikon® Digital Single Lens Reflex (DSLR) camera (*Nikon, Tokyo, Japan*) with a basic 18-55mm lens, and microscopic examination utilising a Leica MZ16FA® Stereomicroscope (*Leica Microsystems, Heerbrugg, Switzerland*). The same stereomicroscope was also used to accurately profile the tooth surface to give an amount of surface roughness.

Teeth were mounted on a featureless free-motion headform (FFMH) derived from a modified Hybrid III dummy head using Aquasil dental putty *(Dentsply Caulk, Milford USA)*, as shown in Fig. 1. The airbag deployment exercise was undertaken in a purpose-built laboratory designed specifically to assess the quality and performance of airbags by various car manufacturers. The airbag test rig met the designated requirements for airbag testing but was modified to meet the needs of this research by incorporating four movable metal tubes to assist in the placement of the dummy head. Airbags were deployed in five different positions relative to the head, with respect to distance and angulations, as shown in Table 1. The deployment is demonstrated in Fig. 2.

A few months after the first episode of airbag deployment, a supplementary test was performed. Two teeth were re-exposed to a second airbag deployment, at half the original distance in order to accentuate potential injury.

Fig. 1: *Tooth mounting on crash test dummy head*

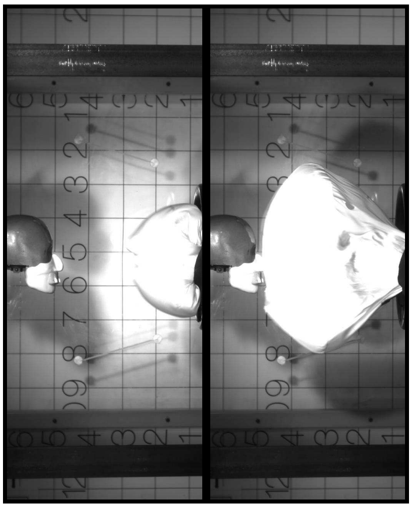

Fig. 2: *Dummy head position during airbag deployment*

Analysis of the existence of crack lines and wear was limited to describing presence or absence of such features. Quantitative analysis was performed by measuring the surface roughness of the tooth surface and determining peak-to-valley surface roughness (Ra) values. Surface profiles were generated relative to an initial plane of reference for selected segments (incisal 1/3, middle 1/3 and cervical 1/3). The data were tabled and centre-line-average values were determined.

Table 1: *Details of the position of each tooth*

Sets of teeth	Tooth	Position on dummy head	Distance from steering wheel (cm)	Angulation from steering wheel
Set 1	1	13/14 area	40.0	Central
	2	12/11 area	40.0	Central
	3	21/22 area	40.0	Central
	4	23/24 area	40.0	Central
Set 2	5	13/14 area	25.0	Central
	6	12/11 area	25.0	Central
	7	21/22 area	25.0	Central
	8	23/24 area	25.0	Central
Set 3	9	13/14 area	25.0	Offset to the right
	10	12/11 area	25.0	Offset to the right
	11	21/22 area	25.0	Offset to the right
	12	23/24 area	25.0	Offset to the right
Set 4	13	13/14 area	25.0	Offset to the left
	14	12/11 area	25.0	Offset to the left
	15	21/22 area	25.0	Offset to the left
	16	23/24 area	25.0	Offset to the left
Set 5	17	13/14 area	25.0	(25.0 cm) Above from the centre
	18	12/11 area	25.0	(25.0 cm) Above from the centre
	19	21/22 area	25.0	(25.0 cm) Above from the centre
	20	23/24 area	25.0	(25.0 cm) Above from the centre

Table 2: *Surface roughness (Ra) values of all teeth pre and post deployment*

SET	TOOTH	INCISAL 1/3		MIDDLE 1/3		CERVICAL 1/3	
		PRE	POST	PRE	POST	PRE	POST
SET 1	1	3.274	2.687	2.729	2.434	1.903	1.640
	2	1.079	1.276	2.306	2.479	3.056	3.389
	3	4.031	3.196	1.644	2.010	2.018	2.050
	4	1.427	1.310	1.535	1.472	2.841	2.770
SET 2	5	1.046	0.941	1.741	1.673	3.124	2.740
	6	1.764	1.705	2.598	2.546	2.259	1.909
	7	1.995	1.499	1.862	1.827	4.938	4.615
	8	3.751	3.654	2.240	2.107	3.751	2.870
SET 3	9	1.197	1.109	1.934	1.820	1.394	1.466
	10	0.782	0.839	1.275	1.286	1.135	1.061
	11	1.240	1.388	1.428	1.300	1.314	1.373
	12	4.250	4.195	2.666	2.300	1.337	1.291
SET 4	13	3.639	3.751	1.404	2.388	0.801	0.821
	14	1.077	1.087	1.659	1.100	1.759	1.870
	15	1.481	1.514	1.664	1.500	0.568	0.845
	16	1.181	1.173	3.128	3.173	1.780	1.581
SET 5	17	2.335	2.351	3.193	3.100	5.777	5.689
	18	3.723	3.807	1.756	1.725	1.428	1.493
	19	1.081	1.032	1.995	1.797	3.043	3.569
	20	1.643	1.660	1.441	1.087	1.857	1.990

RESULTS

A comparison between all observation data of pre- and post-airbag deployment showed no changes to tooth surface. Pre-existing crack lines and areas of wear were unchanged after deployment event. The tooth wear pattern documented in the case report was not observed on any tooth. Table 2 shows the calculated surface roughness (Ra) value (in µm) for each area on each tooth pre- and post-airbag deployment. Student T-test showed no significant difference between Ra values pre- and post-deployment for all teeth ($p>0.05$), and no significant difference between the different sets of teeth.

DISCUSSION

The phenomenon of tooth wear refers to a non-carious loss of tooth structure and is generally classified into four categories; attrition, erosion, abrasion and abfraction.[18] Attrition results from tooth on tooth grinding. Erosion reflects the chemical dissolution of tooth substance without the presence of plaque. Abrasion results from the friction of exogenous material forced over the tooth surfaces, while abfraction refers to the microstructural loss of tooth substance in areas of stress concentration.[18,19] The object of the study was to reproduce a tooth wear pattern attributed to airbag injury.[17]

The sample size for the study was set to twenty teeth in order to simulate the angles and positions of the teeth affected in the previous report. Conservative clinical practice limits the availability of upper anterior teeth. The rationale behind the three levels of observation was to replicate typical observational modus operandi (i.e naked eyes, clinical photographs and enhanced observation). If these initial tests showed some effects on the tooth surfaces, the sample size would have been increased to further statistically defined the changes. Different variables such as the effect of friction from the air bags, the actual gas from the air bags or the combination effect of both factors would then have been assessed. However, not only did the testing fail to produce the same pattern described by De Salvia *et al.,*[17] no evidence of tooth wear of any type could be demonstrated visually or microscopically. A comparison of pre- and post-airbag deployment surface roughness, considered a measure of "micro-wear" caused by the airbags, showed no significance differences.

The only demonstrable difference was in the supplementary test, where two teeth were re-exposed to a second airbag deployment, at half the original distance. Additional minor vertical cracking only was noted, however, the close proximity of the dummy head to the steering wheel was not realistic, representing an extreme 'out of position' scenario. Driving so close to the steering wheel, even for people of short stature, would be uncomfortable and dangerous. The teeth were also exposed for a second time which in real life would be a rare event. In addition, extracted teeth, especially if they are dry, are more brittle and are predispose to fracture. It is acknowledged that a severe force on teeth can cause cracks and/or fracture – features documented in motor vehicle accidents; however this is not tooth wear as described in the case report.[17]

In this study the unconventional arrangement of the teeth in the dummy head was deliberately designed to maximise the forceful interaction between the airbag and the teeth. The intention was to promote tooth wear if possible; therefore, no "soft tissue" simulation over the teeth was contemplated. The extreme measure of deploying the airbags onto the unprotected teeth further demonstrated that deployment forces are incapable of any form of wear, whether at a macro or micro scale. Although the cushioning effect of the putty used to hold the teeth in place may have reduced the forces to some degree, we argue that such an effect is negligible and no different to the effects of the periodontal ligament in real life.

Although saliva found in the mouth acts as a lubricant and has the effect of reducing wear[20] this was purposely not considered in the experimental design. The aim was to encourage wear to occur.

Airbags are usually made of woven nylon.[2] The woven type stitching increases the strength of a fabric especially if it needs to withstand high temperatures, such as those resulting during airbag deployment. Although, this type of fabric can be considered "rough" and abrasive and the surface may be capable of causing other surfaces to abrade (i.e soft tissue), it is unlikely to be able to wear a harder surface like enamel with a single deployment.

This study was limited to one type of airbag. Although most airbag design is based on similar principles, it would be interesting to see whether differences in airbag materials and construction would produce different effects. The distance between the dummy head and the steering wheel could take into account the typical head positions at deployment based on kinematic reconstruction of actual crashes.

More in depth experimentation on the effect of motor vehicle airbags on tooth surfaces may be an appropriate topic for future research. Accident reconstruction is a very complex process but provided that enough information is collated, the kinematic sequence of an occupant in an accident can sometime be reproduced. In general the study of the wearing process of teeth is ongoing and multifaceted. These two complex issues when combined require detailed planning if one wishes to really understand both mechanisms.

CONCLUSION

The primary intention of this study was to examine the possibility of tooth wear following airbag deployment and to recreate the tooth wear pattern described in the referred case report.[17] This *in vitro* study did not reproduce changes to the teeth reportedly following the airbag deployment in the actual crash. Macroscopic and microscopic examination of the labial surface of all incisors tested appears to show no evidence of change after various directional forces from airbags were applied.

Compensation for injury is common in many countries; however in case of liability, it is usually necessary to prove, on the balance of probability, a direct causal relationship between the injury and the accident. Clinical experience and the *in vitro* testing in this project suggest that the damage to the teeth in the documented case was not caused by the deployment of the airbag in the crash.

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REFERENCES

1. Marsh JC. Supplemental airbag restraint systems: Consumer education and experience. SAE 930646 1990. Pennsylvania: Society of Automotive Engineers.

2. Struble DE. Airbag technology: what it is and how it came to be. SAE 980648 1998. Pennsylvania: Society of Automotive Engineers.

3. Wallies LA, Greaves I. Injuries associated with airbag deployment. Emerg Med J 2002;19:490-3.

4. Patrick LM, Nyquist GW, Trosien KR. Safety performance of shaped steering assembly airbag. DOT contract FH-11-7607, General Motors.

5. Suhr M, Kreusch T. Burn injuries resulting from (accidental) airbag inflation. J Craniomaxillofac Surg 2004;32:35-7.

6. Vitello W, Kim M, Johnson RM, Miller S. Full thickness burn to the hand from an automobile airbag. J Burn Care Rehabil. 2000;21:288-9.

7. McKay MP, Jolly BT. A retrospective review of airbag deaths. Acad Emerg Med 1999;6:708-14.

8. Kastanioudakis I, Exarchakos G, Ziavra N, Skevas A. Permanent bilateral acoustic trauma due to airbag deployment in a young female adult. J Trauma 2007;50:79-81.

9. Duma S, Kress T, Porta D, Woods C, Snider J, Fuller P, Simmons R. Airbag induced eye injuries: a report of 25 cases. J Trauma 1996;41:114-9.

10. Garcia Jr R. Airbag implicated in temporomandibular joint injury. Cranio 1994;12:125-7.

11. Duma S, Jernigan M. The effects of airbags on orbital fracture patterns in frontal automobile crashes. Ophthal Plast Reconstr Surg. 2003;19:107-11.

12. Gault JA, Vichnin MC, Jaeger EA, Jeffers JB. Ocular injuries associated with eyeglass wear and airbag inflation. J Trauma 1995;38:494-7.

13. Hollands CM, Winston FK, Stafford PW, Shochat SJ. Severe head injury caused by airbag deployment. J Trauma 1996;41:920-2.

14. Gottesman M, Sanderov B, Ortiz O. Carotid artery dissection and stroke caused by airbag injury. Am J Emerg Med 2002;20:372-4.

15. Polk J, Thomas H. Automotive airbag induced second degree chemical burn resulting in staphylococcus aureus infection. JAOA 1994;94:741-3.

16. Smock WS. Airbag related injuries/Accident Investigation. In Siegel JA, Saukko PJ, Knupfer GC (Editors). Encyclopedia of Forensic Sciences. London: Academic Press; 2000. Vol 1:1-9.

17. De Salvia.A., Sergolini.L and Pescaralo.D. An Atypical Air bag injury. J Forensic Odontostomatol 2007; 25:57-60.

18. Grippo JO, Simring M, Schreiner S. Attrition, abrasion, corrosion and abfraction revisited: a new perspective on tooth surface lesion. JADA 2004;135:1109-18.

19. Kelleher M, Bishop K. Tooth surface loss: an overview. Br Dent J 1999;186:61-7.

20. Kaidonis JA, Townsend GC, Richards LC, Tansley GD. Wear of human enamel: a quantitative in vitro assessment. J Dent Res 1998;77:1983-90.

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