Analysis of injuries requiring ophthalmological check-ups because of frontal vehicle collisions

Masahito Hitosugi¹*, Marin Takaso¹, Atsuko Matsumoto¹, Takeshi Koseki¹, Satoshi Furukawa¹, Koji Mizuno²

Abstract: The patients suffering from severe upper or middle facial injuries have to be checked-up ophthalmologically because they might receive strong forces surrounding the eyes. This study investigates the patterns and severity of ocular and severe upper or middle facial injuries from real-world vehicle collisions in Japan.

We collected data on vehicle passengers with any ocular injuries, or upper or middle facial fractures (OIFF) who were involved in frontal collisions. Data were obtained from in-depth data records from the Institute for Traffic Accident Research and Data Analysis (ITARDA), Japan from 1993 to 2005. Collision information and victims' medical data were reviewed.

The 30 victims had a mean age of 33.0 ± 14.0 years with an equivalent barrier speed of 43.4 ± 14.6 km/h. The mean ISS was 10.4, and the face was the region with the highest AIS score (1.5). Most of the victims with OIFF (29/30) were involved in collisions without deployment of airbags. No significant differences in mean age, height, weight, ISS, AIS scores of the victim, EBS of the involved vehicles were found between victims with seatbelt and those without.

Victims with OIFF need to be checked-up ophthalmologically after the collision; such treatment will likely improve their quality of life. Subsequently, conflict owing to the insufficient diagnosis and/or inappropriate management would be prevented.

Key Words: vehicle collision, ocular injury, upper or middle facial fracture, injury severity, safety device.

Motor vehicle collisions (MVCs) are the leading cause of maxillofacial injuries and are among the most frequent cause of facial fractures [1–3]. Ocular injury is also a common cause of ophthalmic morbidity and monocular visual loss, and comprises 5% of all ophthalmic admissions in the developed world [4]. In the United States, among the occupants involved in police-reported frontal vehicle collisions, 18 per 1000 occupants suffer from ocular injuries [5]. Because MVCs are responsible for a large number of ocular injuries, prevention of MVC-related ocular injuries will require the identification of characteristics associated with their occurrence [5]. We previously analyzed maxillofacial injuries of the vehicle drivers [6]. However, there is no comprehensive research on the requirement of ophthalmological check-ups by integrating information from collision details and human injuries. We considered that the patients suffering from upper or middle facial injuries have to be checked-up ophthalmologically because patients might receive strong forces surrounding the eyes.

The present study aimed to clarify the background of the patients with ocular and severe upper or middle facial injuries based on real-world vehicle collisions.

MATERIAL AND METHODS

Data collection
Samples were collected from the data records of the

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Institute for Traffic Accident Research and Data Analysis (ITARDA). ITARDA’s specialized investigators visit the scene of recent collisions to interview the individuals involved and to examine the vehicles and traffic situations. External damage profiles of the involved vehicles are prepared, and internal vehicle intrusions and contact marks are documented. Additionally, the equivalent barrier speed (EBS) of the involved vehicles is calculated from the damage measurements and the known weight of the vehicles. Field data are also collected on many aspects, including emergency rescue and medical conditions, and physical injuries. This in-depth analysis is only active in the Japanese cities of Tsukuba and Tsuchiura, and their surrounding areas.

Data on adult vehicle passengers (older than 17 years old) who were involved in a frontal collision from 1996–2005, were collected from in-depth data of ITARDA. The involved vehicles were limited to passenger cars, including sedans, sport-utility vehicles, and light trucks (heavy vehicles were excluded). “Frontal collision” was defined as the principal direction of force being directly from the front of the vehicle, plus or minus 45°. From these cases, we chose the patients with ocular injuries, or upper or middle facial fractures (OIFF). The following data were collected from collision reports: how and where the collision occurred, the type of vehicle involved, the EBS of the vehicle at the time of impact, the seating position of the patient, and whether a seat belt was used and airbags were deployed. Age, physical stature (body height, weight, and body mass index), data on the injured region, and injury type were examined by referring to each patient’s medical data. Furthermore, in reviewing the injury data, objective measures of injury severity, the injury severity score (ISS) and the 1990 revision of Abbreviated injury scale (AIS), were calculated for each patient [7, 8]. Collision cases were excluded from analysis if information regarding the direction of impact, the point of collision, or the status of safety devices was missing. This study and submission of the results were approved by the review of the Committee of ITARDA and the National Police Agency in Japan; the study adhered to the tenets of the Declaration of Helsinki.

**Statistical analysis**

The Mann–Whitney test was used to compare the differences in mean age, height, weight, ISS and AIS score of the victims as well as the EBS of the involved vehicle. Differences with a p value less than 0.05 were considered significant.

**RESULTS**

Obtained mean values are shown in mean ± standard deviation.

1) General characteristics

From the 3631 cases of in-depth collision data investigated by ITARDA over 10 years, a total of 30 victims (21 males and 9 females) from 29 collisions were reviewed for this study. Most of the patients (73.3%) were drivers, followed by front-seat passengers (16.7%), and rear-seat passengers (10.0%). Their ages ranged from 18–84 years, with a mean age of 33.0 ± 14.0 years. With regard to the physical stature of the patients, their mean height was 166.0 ± 7.8 cm (range, 152.0–180.0 cm), mean weight was 60.7 ± 10.9 kg (range, 45.0–85.0 kg), and mean body mass index was 21.8 ± 3.2 (range, 18.0–28.0). The mean EBS of the involved vehicles was 43.4 ± 14.6 km/h.

2) Characteristic of injury

Ocular injuries were present in four cases (corneal laceration, 2 cases; retinal laceration, 1 case; scleral laceration, 1 case). Upper or middle facial fractures were present in 26 cases. With regard to fractures, a nose fracture was the most common (15 cases), followed by maxillary fracture (10 cases), orbital fracture, and zygomatic fracture (3 cases each) (Fig. 1).

The ISSs ranged from 2–38 (mean: 10.4 ± 9.4) (Fig. 2). For each body region, the face was the region with the highest AIS score (1.5 ± 0.6), followed by the lower extremities (1.2 ± 1.2), chest (0.9 ± 0.5), upper extremities (0.5 ± 0.5), head (0.3 ± 0.7), abdomen (0.2 ± 0.6), and neck (0.2 ± 0.4).

**Figure 1.** Number of ocular injuries and fractures in the upper or middle face.

**Figure 2.** Distribution of ISS in all victims.
3) **Comparison of injury severity and collision characteristics by seat belt use**

We subdivided the victims according to the seating position and safety restraint use (Table 1). Restraint classifications were based on airbag deployment in combination with seat belt use. Most of the victims with OIFF (29/30) were involved in collisions without deployment of airbags. For the 29 cases, we divided for two groups according to the seatbelt use and compared the backgrounds and injury severity of the victims. No significant differences in mean age, height, weight, ISS, AIS scores of the victim, EBS of the involved vehicles were found between victims with seatbelt and those without.

### Table 1. Number of passengers according to the seating position and the use of safety devices

<table>
<thead>
<tr>
<th></th>
<th>Seatbelt +</th>
<th>Seatbelt -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver</td>
<td>Airbag +</td>
<td>Airbag -</td>
</tr>
<tr>
<td>Front seat passenger</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Rear seat passenger</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>All passenger</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>

OIFF: ocular injury or fractures in the upper or middle face.

### Table 2. Comparison of mean age, height, weight, ISS, AIS scores of the victim, EBS of the involved vehicles between victims with seatbelt and those without

<table>
<thead>
<tr>
<th></th>
<th>+ (n=7)</th>
<th>- (n=22)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>35.7 ± 14.7</td>
<td>32.1 ± 14.3</td>
<td>0.61</td>
</tr>
<tr>
<td>EBS (km/h)</td>
<td>46.4 ± 11.8</td>
<td>43.6 ± 15.1</td>
<td>0.56</td>
</tr>
<tr>
<td>ISS</td>
<td>11.6 ± 8.4</td>
<td>10.5 ± 10.0</td>
<td>0.41</td>
</tr>
<tr>
<td>AIS Head</td>
<td>0.3 ± 0.8</td>
<td>0.3 ± 0.8</td>
<td>0.97</td>
</tr>
<tr>
<td>AIS Neck</td>
<td>0.1 ± 0.4</td>
<td>0.2 ± 0.4</td>
<td>0.82</td>
</tr>
<tr>
<td>AIS Face</td>
<td>1.4 ± 0.8</td>
<td>1.6 ± 0.5</td>
<td>0.42</td>
</tr>
<tr>
<td>AIS Chest</td>
<td>1.0 ± 1.7</td>
<td>0.8 ± 1.4</td>
<td>0.93</td>
</tr>
<tr>
<td>AIS Abdomen</td>
<td>0.3 ± 0.8</td>
<td>0.2 ± 0.5</td>
<td>0.90</td>
</tr>
<tr>
<td>AIS Upper Ext.</td>
<td>0.9 ± 1.2</td>
<td>0.4 ± 0.7</td>
<td>0.32</td>
</tr>
<tr>
<td>AIS Lower Ext.</td>
<td>1.0 ± 1.2</td>
<td>1.3 ± 1.2</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Values are represented as mean ± standard deviation. Ext.: extremities.

In vehicle collisions, life-threatening injuries have to be managed immediately. Because ocular and facial injuries are seldom fatal, they are often considered minor injuries and are assigned little weight in measures of injury severity [8-10]. If the victim suffers from upper or middle facial fractures, the eyes may receive forces to some extent, and ophthalmological check-ups is required. In most cases, as the victims aware of abnormalities of ocular function or symptom, they refer to ophthalmologists. However, some victims are not referred to an ophthalmologist after the collision because of the delay of recognition of abnormalities. In reports from developing countries, a time delay in presenting to hospital after the injury has been described. In a review of pediatric ocular trauma, 34% of patients presented to hospital after 24 hours of injury [11]. Another epidemiological study showed that one in three patients presented to the hospital 8 or more days after injury [12]. These phenomena were mainly owing to poor access to appropriate healthcare facilities for social and economic reasons, and a low level of literacy of the patients. Even in developed countries, some victims may lose the chance to be referred to an ophthalmologist.

In our series, mean EBS was 43.4 km/h. At a high speed impact, passengers move forward because of rapid deceleration, and strong contact with the interior of the vehicle occurs, especially for the face and lower extremities. For victims with facial injuries and further polytrauma owing to high speed frontal collision, ophthalmological assessments are required. In considering prevention, medical doctors should also be concerned with contact between the face and the vehicle's interior.

We also considered the interaction of restraint devices and OIFF. The benefits of the use of a seat belt (reduction in fatality rate and injury severity) are widely accepted. A previous report suggested that a lack of seat belt use was associated with a 2-fold increase in the risk of ocular injury [5]. Therefore, proper seat belt use is a highly effective means not only to reduce the risk of injury in general, but specifically to reduce the risk of
ocular injury, which is a message that ophthalmologists should be sharing with their patients.

However, in this study, seven drivers and front seat passengers using seat belts also sustained OIFF. When comparing the ISS and AIS score between belted and non-belted victims, no significant differences were found. This finding suggests that even if vehicle occupants are wearing seat belts, the drivers and front seat passengers have sufficient forward movement for contact of their faces with the vehicle when involved in a high-speed collision. Immediately upon the start of a collision, restrained drivers and passengers continue to move forward horizontally for a short distance until they are stopped by the seat belt or by impact with the vehicle's interior. Previously, clinical studies suggested that seat belt use did not decrease the incidence of major maxillofacial fractures and severity of facial injuries [13, 14]. Because some restrained drivers still sustain maxillofacial fractures due to impact with the steering wheel, further protection for the face is necessary. Therefore, airbags as a supplemental restraint system are important.

Airbags protect motor vehicle passengers by providing a cushioning barrier between them and the vehicle interior’s hard surfaces. The benefit of airbags in reduction of drivers’ fatality is well recognized [15]. Major et al. suggested that among airbag-restrained victims, half of them sustained maxillofacial injuries, the majority of which were minor injuries, such as abrasions, contusions, or lacerations [9]. They also found that there were no severe or serious injuries among airbag-restrained victims [9]. Some previous studies that investigated maxillofacial injuries and safety tools also agreed that combined use of seat belts and airbags significantly reduces fractures compared with completely unrestrained occupants [9, 16-18]. Therefore, the trend shown in our analysis that only one in 30 restrained victims with airbag deployment suffered from OIFF is consistent with these findings.

There is great concern that airbags can cause ocular injuries [19-22]. In an adjusted model of vehicle passengers, airbag deployment was associated with a 113% increased risk of ocular injury [5]. Furthermore, frontal airbags were the most common noted source of ocular injury among occupants of 1993 and later model year vehicles. This previous study also suggested that the majority of ocular injuries were minor and likely resulted in no permanent loss of visual function [5]. However, a review of a vehicle crash database from 1997–2005 suggested that airbags induce orbital blow-out fractures [23]. Although these fractures were solely attributed to airbag deployment, nine of 10 occupants were positioned at the airbag’s deployment zone at the time of impact, the so-called “out-of-position”, as a result of being unrestrained, falling asleep, and having decelerated before impact. Three victims with orbital fracture in our study were all unrestrained passengers without airbag deployment. With direct contact of the face with the steering wheel, B-pillar, or windshield, airbag-induced OIFF may be rare among uprightly-seated, restrained occupants.

CONCLUSION

This is the first report to show the ocular injuries and severe upper or middle facial injuries among victims who were involved in real-world frontal vehicle collisions. Victims with OIFF need to be checked-up ophthalmologically after the collision; such treatment will likely improve their quality of life. Subsequently, conflict owing to the insufficient diagnosis and/or inappropriate management would be prevented. Additionally, to prevent severe ocular injuries, correct use of seat belts with airbag deployment is required.

Conflict of interest. The authors declare there is no conflict of interests in this study.

Acknowledgment. The present research was presented at the Meeting of Multi-faced Analysis of Accidents, 2007 at ITARDA [24].

References