Aviation Maxillofacial Shields and Blunt Impact Protection in U.S. Army Helicopter Mishaps

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BACKGROUND: Maxillofacial shields (MFSs) are an available piece of aviation protective equipment designed to integrate into aircrew helmets and protect the face from wind and flying debris. Aviators have anecdotally reported that MFSs have provided blunt impact protection during impact events (i.e., a crash); however, no such cases have been formally documented in the literature.

CASE REPORTS: Two cases were identified where aircrew wearing MFSs were involved in mishaps resulting in maxillofacial blunt impacts. In the first case, an OH-58 pilot struck the cyclic with his head/face during a crash. In the second case, a CH-47 crew chief was struck in the face by a maintenance panel dislodged from the aircraft. In both cases the MFS was damaged, but neither service member experienced injuries as a result of impact to the face.

DISCUSSION: The cases illustrate the effectiveness of the MFS against blunt impact during aviation mishaps. While MFS use is currently optional for aircrew, it is believed that increased MFS use would result in fewer or less severe facial injuries as well as decrease the associated time and monetary losses due to injury.

KEYWORDS: maxillofacial shield, face shield, facial protection.

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Facial injuries are common in helicopter mishaps. In 2003, Taneja et al. reported that 47.6% of fatally injured helicopter pilots had sustained facial injuries.[12] In nonfatal crashes, the spectrum of injuries spans the range from minimal to extensive. In the short term, facial injuries can result in mission failure or hinder aircraft egress. In the long term, they can result in loss of function or facial disfigurement requiring extensive surgery, rehabilitation, and psychological treatment.[7] Maxillofacial shields (MFSs) are an optional component of personal protective equipment (PPE) that integrate with the HGU-56/P flight helmet shell and visors. The MFS is designed to mitigate some facial trauma, particularly that caused by low energy projectile threats (spall, debris, etc.), as well as protect the user's face from the wind. The current paper reviews two U.S. Army helicopter mishaps during which aircrew wearing MFSs were protected against blunt impact. The purpose in reporting these cases is to illustrate the effectiveness of the MFSs against nonballistic facial injury and to open a discussion exploring its use, or nonuse, in the U.S. Army's aviation community.

CASE REPORTS

In 2008, a U.S. Army OH-58D Kiowa Warrior scout helicopter was engaged in a routine nap-of-the-earth (low-altitude flight following terrain contours used to avoid enemy detection) training mission through mountainous terrain in good weather, when unexpectedly the tail rotor struck the side of a hill. The resulting loss of tail rotor effectiveness caused the aircraft to spin out of control, bounce on the ground, and finally come to rest inverted (**Fig. 1A**). The aircraft was considered a total loss, resulting in the crash being classified as a Class A mishap.

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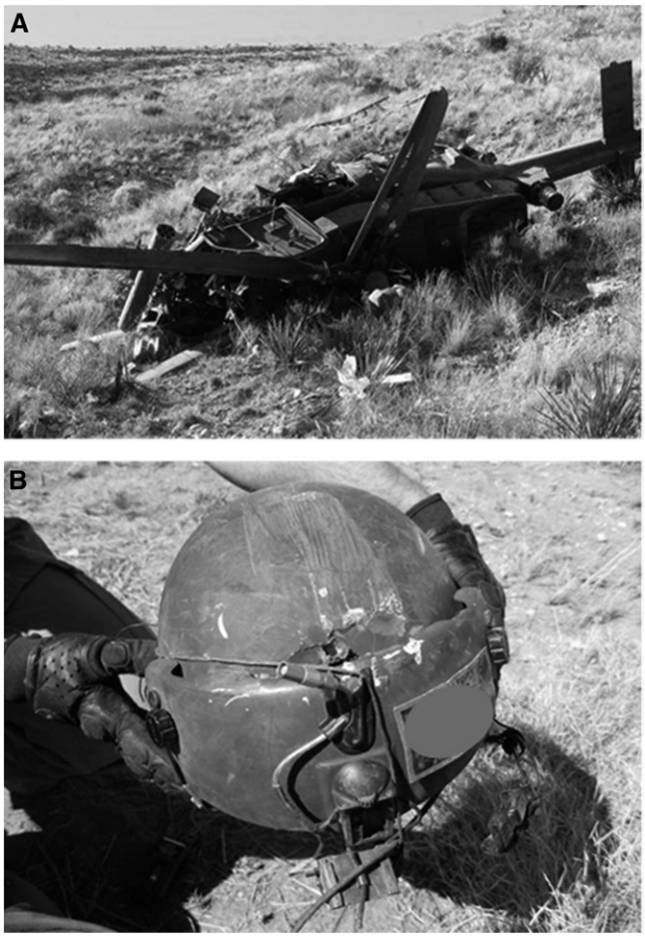

Fig. 1. A) OH-58D crash. B) HGU-56/P flight helmet of the pilot in the left seat with damage above the visor housing due to blunt impact.

Fig. 2. MFS worn by OH-58D pilot during mishap. A) Front side of the MFS with chipped paint indicating impact locations over the areas protecting the nose and right mandible. B) Back side of the MFS with slight paint chipping on the interior surface protecting the right mandible (image bottom left).

The helicopter was being operated by a pilot (PI) seated in the left seat and a pilot-in-command (PC) seated in the right seat. Both pilots were wearing an HGU-56/P flight helmet with visors deployed. The PI was wearing an MFS in addition to his standard PPE, while the PC was not wearing any additional optional PPE. During the crash, both pilots sustained frontal impacts to their HGU-56/P helmets (**Fig. 1B**) and both pilots reported being rendered temporally unconscious (PC: ~1 min, PI: ~5 min) from the impact. The PC impacted the cyclic at the visor/nose interface, which resulted in a significant nostril laceration and contusion of the left eye. Additionally, he sustained multiple vertebral fractures due to deceleration. The PI impacted the cyclic in the lower face region protected by the MFS. He sustained a compound fracture of his right lower leg and a simple fracture of the right medial ankle in the collapsing aircraft structure. Additionally, his coccyx was fractured on impact. Only minor scratches were reported on his head and face. Examination of witness marks on the PI's MFS revealed two impact locations (**Fig. 2**): one at the lower right quadrant of the MFS that protected the mandible and one in the middle of the MFS that protected the nose. Cracking of the MFS's material (approximately 26 mm in length) was noticed at the lower right impact location and corresponding interior surface.

In 2010, a U.S. Army CH-47F Chinook cargo helicopter was performing a routine resupply mission when the #2 engine failed. During an attempted gliding landing, the rear of the aircraft came to rest on a stone wall topped by a metal fence. The front of the aircraft landed on the ground in a nose low attitude, resulting in a rotor ground strike. The aircraft was a total loss, resulting in the crash being classified as a Class A mishap. The aircraft was carrying 2 pilots, 2 crew chiefs/flight engineers, a gunner/tech observer, and 22 passengers at the time of the mishap. Four minor injuries resulted from the crash.

During the engine failure (prior to the crash landing), a maintenance panel blew off the aircraft wall, striking one of the crewmembers in the face. The crewmember was standing approximately 12″ (0.30 m) from the panel and was wearing an HGU-56/P flight helmet with an MFS attached when impacted. The resulting impact caused the MFS to break away from the helmet and knocked the crewmember to the cabin floor. Examination of witness marks on the MFS (**Fig. 3**) revealed the location of impact to be just above the middle of the MFS (approximately 65 mm from the bottom edge of the shield) in the region protecting the maxilla. Material damage at the impact site (approximately 22 mm long, 4 mm wide)

Fig. 3. MFS worn by CH-47F crewmember struck by dislodged maintenance panel. A) Front side of the MFS with chipped paint and material damage at the impact location over the area protecting the maxillary region. B) Back side of MFS with chipped paint and material damage on the interior surface the impact location.

extended through the MFS, with noticeable damage on the interior surface. The crewmember sustained no facial injuries.

DISCUSSION

Case #1 is unique in that it presents a side-by-side comparison of two pilots, one wearing an MFS and the other not, who experienced similar crash dynamics. Both pilots impacted their cyclic, impacted their head, damaged their helmet, and were rendered unconscious. From the crash analysis, it is unclear what injuries the PI might have sustained had he not been wearing an MFS. It is likely, based on location of the impact marks on the MFS, that the PI escaped what could have been very severe injuries. The PC was not wearing an MFS and his injuries (contusion of the eye and laceration of the nose) were only somewhat mitigated by his protective visor. The PC's injuries may have been further moderated if he had been wearing an MFS as well.

In contrast to the first case, in the second case a piece of debris impacted a crewmember in the face. The force of the impact was strong enough to crack and dislodge the MFS and knock the crewmember down. Based on the witness mark locations and the force of the impact, it is quite likely that the crewmember would have sustained substantial damage to the maxilla and nasal regions.

The military rotary-wing aircrew risks ballistic, impact, and acceleration injuries during military operations, especially during crashes. The MFS covers a relatively extensive area of the face that would otherwise be exposed to injury. The severity of facial injuries can vary from superficial soft tissue lacerations to compound, complex bone fracture, the ramifications of which are equally variable. The disfiguring aspects of such injuries can be long lasting and socially debilitating.[5] Additionally, facial injuries can have immediate operational consequences by potentially interfering with a crewmember's vision and/or ability to communicate.

Mandible injuries among aircrew are of special interest due to the mandible's relatively large area (lower third of the face) and its morphological prominence. Mandibular fractures are painful and require extensive time for repair, with 75% of adults comparable in age to military helicopter pilots requiring 3 to 4 wk to heal uncomplicated mandibular fractures.[2] Several studies have also suggested a correlation between mandible fracture and loss of consciousness,[9] concussion,[11] and basilar skull fracture.[8] Such injuries might further degrade an injured aviator's ability to react to environmental hazards, hindering their ability to escape and evade.

As severe as facial injuries are, they are not that uncommon. Barth analyzed 156 U.S. Army noncombat aircraft mishaps occurring from 2003 to 2005 contained in the U.S. Army Combat Readiness Center database.[4] Results showed that of 606 aircraft occupants injured (407 fatally injured, 199 nonfatally injured), 132 sustained face and jaw injuries (45 fatally injured, 87 nonfatally injured).[3] The reason for these facial injuries are varied. All occupants are at risk for impacting surfaces within the flail arc of the head during any rotary-wing aircraft mishap. Certain cockpit configurations can increase this risk; with centrally located targeting systems (common in attack helicopters), the break-away cyclic, and sighting devices posing a documented threat to the face and head during crashes.[1] Additionally, nonballistic spall such as from fragmenting ordnance and windshield shards pose risks as well.

In the cases presented, all of the aircrew were using the standard issue HGU-56/P flight helmet at the time of the mishap. This helmet is designed "to provide a custom fitted helmet affording acoustic, eye, and head protection for aircrew personnel."[6] The addition of the MFS completes the protection provided by the HGU-56/P by covering a previously exposed region of the face. The fully integrated helmet system effectively protects the entire head against blunt impact, low energy fragments such as ballistic spall, and, to an extent, fire.

The witness marks on the helmets worn in the cases presented demonstrate that, when used as a complete system, MFSs are very effective against blunt impact. This begs the question of why this important piece of PPE remains optional

and why some aircrew elect not to use it. Anecdotal reports suggest that MFSs are more popular among crew than pilots, due to the improved communication ability it provides. This might suggest that MFSs are more useful for specific operational tasks, or alternatively are a hindrance during others.

A search of the literature revealed no studies of MFS user acceptance among aircrew. MFSs under development for dismounted and ground-mounted troops have been shown to reduce the user's field of view when compared to just wearing a combat helmets alone.[4] While the aviation MFSs have a very different profile, field of view issues should be considered, especially when head/torso rotation is limited. Reduced situational awareness, lack of familiarity, and design issues have also been noted as reasons for not adopting new PPE when a choice of PPE was available.[10] While some of these factors were most likely evaluated during initial development, additional examination from an operational perspective is now needed since the MFS has been in service for several decades.

The authors intend for these cases to spur further conversation of MFS use within the aviation community. Further research should continue to investigate the effectiveness of MFSs in preventing injury. To this end, the MFS should be included as an individual item for review (separate from the helmet) in the list of PPE evaluated during mishap investigations in order to help document both their use and effectiveness. Additionally, aircrew, for whom the MFS was designed, should be surveyed to assess its user acceptance. Once reasons for not using MFSs have been identified, materiel and/or doctrinal changes can be properly investigated. This important piece of PPE is effective and commercially available. It is critical that all aircrew benefit from MFS use, thus alleviating a significant injury burden in the aviation population.

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