The Andrews Research and Education Foundation are proud to present the results of testing on the FaceLoc quick release system that has been completed in conjunction with the sponsoring company.

Introduction: The number of catastrophic spinal injuries is higher in football than any other sport in the United States with 736 reported over a 25 year span (1982-2007).[6] Prevention and treatment of these types of injuries is a priority with the National Athletic Trainers Association (NATA) who published a position statement on the subject in 2009.[6] In this statement many recommendations were made including a statement on facemask removal which stated that:

> "the technique used for facemask removal should be the one that creates the least head and neck motion, is performed most quickly, is the least difficult, and carries the least chance of failure."

Over the years many techniques and tools have been developed for removing facemasks in the least obtrusive and fastest ways with a combined tool approach being supported by many authors.[2, 4, 5] Additionally some helmet manufacturers have developed quick release devices for removal such as the Riddell 360 quick release device, the Riddell Revo Revolution device or the Schutt Ion 4D and most have shown good results in both speeding up the removal of a facemask and in preventing spinal movement during removal.[2, 4, 5] Additionally there are techniques for removing standard facemask brackets that have tested well in removal times and safety using a cordless screwdriver or tab cutting technology.[5] The FaceLoc device is a unique and innovative design that could potentially improve the safety and speed of facemask removal, and is currently an add on device for use in multiple helmet designs. One of the major hurdles to any new technology that is an add-on to helmets is that each helmet must be retested in very specific conditions with any individual alteration in order to be certified under NOCSAE testing procedures.[3] In a 2013 statement on add-on devices NOCSAE declared:

> "Companies which make add-on products for football helmets have the right to make their own certification of compliance with the NOCSAE standards on a helmet model, but when that is done, the certification and responsibility for the helmet/third-party product combination would become theirs, (not the helmet manufacturer). That certification would be subject to the same obligations applicable to the original helmet manufacturer regarding certification testing, quality control and quality assurance and licensure with NOCSAE."[3]

This determination is important to ensure that new advances are thoroughly vetted before going to market. As with any new attachment device, testing to determine the strength of the attachment and failure points is essential. One main factor in doing this testing is determining appropriate levels to test the devices. Current literature has safety and impact blow testing measured in acceleration of gravity units (g) for most helmet and facemask testing, which matches up with current NOCSAE approval testing protocols.[1, 7] This however is not designed to test pull out strength or shear force to these attachment devices. A second method would be to compare new technology to older/standard technologies, which has not been done recently in the literature. The primary goal of this evaluation was to examine the ability of this novel device to withstand the forces associated with normal football helmet use.

Study Design: Laboratory Study

Methods: Three different manufacturers' helmets were tested including Rawlings, Riddell, and Xenith. Each of the helmets was fitted with new FaceLOC fastener hardware to attach the face masks to the helmets for each test.

Helmets were put through a series of tests including; a) distraction pulls on the FaceLoc device perpendicular to the mount; b) angled facemask distraction pulls at a 30 degree upward angle as well as a 30 degree downward angle; c) compression testing from the right and left sides of the helmet; d) upward compression from the base of the facemask at 30 degrees; and e) drop testing from a height of 2 meters.

Distraction testing (a and b) was for the individual connectors and for the angled face mask pulls were completed on the Instron 5565 unit (controlled by Instron - Bluehill 2 version 2.19 software) with the helmet braced to the unit using a custom clamping system (See Figure 1). The protocol was designed to apply a tension force at a rate of 1000mm per minute to a maximum load of 500N. At the end of each test the load was returned to between 10-20N and the process was repeated a specified number of times (10 for device pulls, and 20 for facemask pulls) to essentially provide a cyclic test. Individual device pulls were performed at all four connection sites noted in Figure 2a and facemask pulls were performed from an attachment on the middle of the facemask (see Figure 2b).

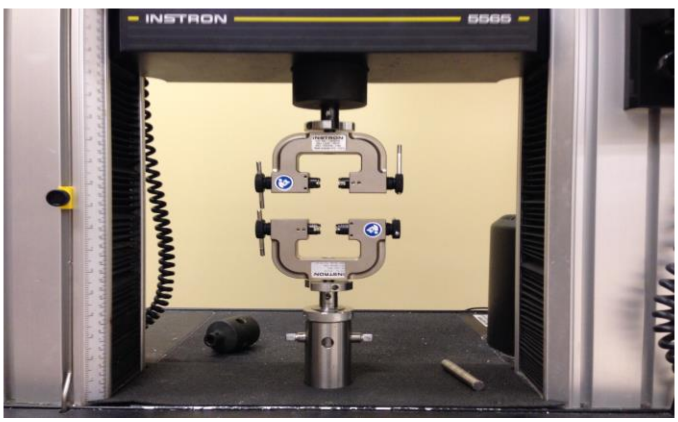

Figure 1 – Instron 5565 with custom clamping system

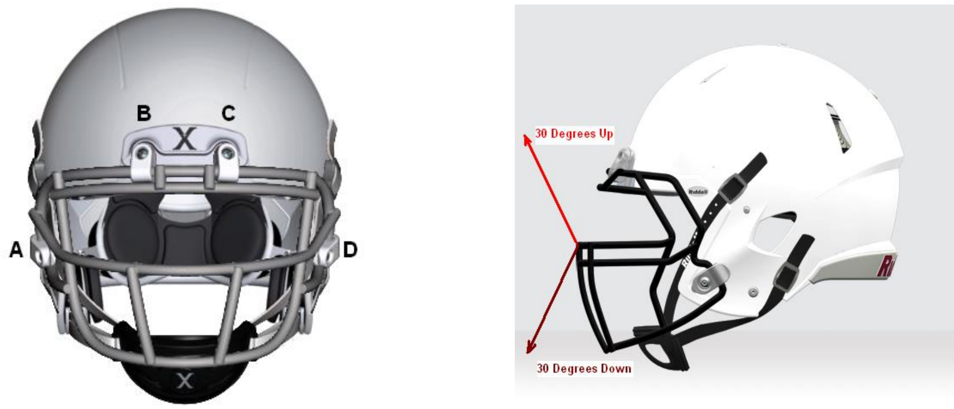

Figure 2a and 2b – Distraction testing sites and angles of pull

Compression testing (c and d) was also performed on the Instron 5565 unit with identical controlling software. These tests were a series of compression trials on the (c) lateral sides of the helmets and an (d) upward force on the face mask. The lateral side compression tests were done perpendicular to the helmet surface in a random order of helmet side selection (right and left), and the random selection of the three helmets. The face mask upward thrust was conducted with the helmet mounted to provide a 30 degree angle relative to the helmet being worn. In this testing the helmets were compressed to 500 N at a rate of 1000mm per minute with 10 cycles for lateral compression and 20 cycles for facemask compression. Compression sites are noted in Figure 3a and 3b.

Figure 3a and 3b – Compression testing sites on the device and facemask

Drop testing (e) was conducted with the goal of replication of an athlete impact of the face mask into a solid surface. A Vicon (Oxford, UK/ Centennial, CO) Nexus 3-D motion capture system was utilized to record the helmet position (240Hz) and analog force data (2400Hz). Four 9mm retro-reflective markers were attached to each helmet surface: lateral markers were placed behind and above the lateral ear holes on the helmets, one marker was placed along the back center line of each helmet 13cm above the base while resting on an even surface, and the fourth marker was attached to the top of the helmet center line, between 3cm forward and 3cm behind the top helmet point. A center of mass height of 2m was selected for the initial start position, with the helmet at rest above a Bertec custom model 4080-09 Force Platform (Bertec Corporation USA, Columbus, OH). The helmets were released with the face mask pointed down. The initial impacts for all helmets was the face mask cross bars. A head mass weight (50.7N), constructed of small sand bags wrapped into a single unit was inserted into the helmet to replicate a human head. The head mass was lightly affixed to the helmet shell with clear cellophane packing tape, and was reset after each impact test to standardize the head mass initial position. No contact between the head mass and the face mask or FaceLOC hardware was permitted.

Results: Distraction testing showed very consistent results across attachment points on all styles of helmet for the individual attachment sites with all sites showing no failures throughout the testing all the way up to the maximum testing level of a 500N pull for each of the 5 trials. Distraction testing in 30 degree angled pulls of the facemask showed similar results with no failures up to 500N pulls over 20 cycles. In an attempt to find a failure point well above expected load rates seen in a football setting, an additional upward pull was done to 1200N with two of the three helmets showing a failure at one connection site, with both being metal fatigue failures at the base of the male fastener (Rawlings at 725N and Xenith at 867N).

Compression testing showed no failures in lateral tests with 10 cycles of 500N of compression from either side of the helmets. In the facemask compression testing, two failures were seen, both in the Xenith helmet, but in a third test there was no failure. Based on examination following the failure it was suspected that there were material defects in the tested device, but caution should be taken in considering this possibility since both failures happened in the same helmet design even though the third test had no issues at a much higher testing level (see Table 1).

HELMET MODEL	Initial test (500N)	Follow-up (1000N)		Explanation
RAWLINGS	20 x 500N	10 x 1000N		
RIDDELL	20 x 500N	10 x 1000N		
XENITH	9 x 500N			Material Failure at Bolt C (462N)
	10 x 500N			Material Failure at Bolt C (419N)
	20 x 500N	10 x 1000N		

Table 1 – Facemask Compression testing results

Drop testing was done on each helmet 12 times, but due to testing malfunctions Force numbers were obtained for 7 trials in the Rawlings helmet (2453.5 ±250.4), 12 trials in the Riddell (2273.2 ± 133.5), and 6 trials in the Xenith (2171.3 ±101.3), but numbers for force generated were fairly constant across trials so lost trials are not expected to effect the results in which no failures of the FaceLoc device were seen. There was however a concern with the fasteners loosening after 6 trials in the Rawlings helmet and after 9 trials in the Xenith. Both were tightened upon discovery and remained tight for the rest of the trials.

Discussion: The testing completed in this study was designed to look at the effectiveness of the FaceLoc connection system for facemasks on multiple helmet designs. The overall testing showed excellent results with minimal failure trials. Distraction tests designed to pull the device apart well exceeded (500N) the failure loads expected to be seen during normal football activity both with individual straight line pulls and in oblique facemask based pulls. No failures were seen in these tests up maximum loads tested over multiple trials. In compression trials no failures were seen in lateral compression of the device, however what looked to be material failure was seen in one helmet design in two of the three trials, but those failures were well below the forces applies in the third test. Additionally these failures were not in the connection device, but instead in the metal stud holding the connection point to the helmet. While this specific helmet design may provide additional shear force on this part of the fixation stud, it is also possible that there was a flaw manufacturing process. While these tests did not make it to the maximum testing values they did still reach high force levels of 419 and 464N, which when evaluated separately are still high failure loads that may not come into play in an actual event.

The last of the tests done were to look more at multiple (20) higher impulse load effect on the device. The forces seen were high on initial impact and no failures in the device were seen, however there was a loosening effect on the base stud that should be evaluated further to make sure that multiple high impulse blows to not loosen the attachment to a failure point. This problem could potentially be solved by some type of thread locking device or substance and if installed by a manufacturer could be a non-issue due to improved fittings. The main finding here of no failures over multiple blows is however very encouraging.

It is important to note that the testing completed here in no way evaluates safety of the device and did not involve NOCSAE certification testing. According to the NOCSAE position statement, any new add-on device should have this testing completed to evaluate the safety of the device with each helmet system on which they could potentially be used, however the ease of use and speed with which the devices can be removed along with the fact that no tool is needed to remove the clips create a very exciting option for improving the treatment of potentially catastrophic injuries on the field. The pairing of this device with a traditional loop attachment also allows for a familiar secondary option for removal that most football medical personnel are familiar with in case of a failure of the primary device.

Overall the device tested well and showed good results in keeping the facemask securely attached to the helmet in multiple stress conditions. Additional testing is recommended in three areas; a) safety testing adhering to NOCSAE standards; b) removal speed testing in new and used devices across skilled and unskilled medical responders; and c) failure testing similar to the work done here after the devices have been used on helmets for varying amounts of time and at different levels to ensure continued integrity of the devices with normal wear and tear.

References:

1. Crisco J, Wilcox B, Macham J. Magnitude of head impact exposures in individual collegiate football players. *J Appl Biomech.* 2012;28(2):174-183.

2. Gruppen T, Smith M, Ganss A. Removal time and efficacy of Riddell Quick Release Face Guard Attachment System side clips during 1 football season. *J Athl Train.* 2012;47(4):421-427.

3. NOCSAE. Certifications to NOCSAE standards and add-on helmet products. *Statement Paper.* 2013.

4. Scibek JS, Gatti JM, McKenzie JI. Successful removal of football helmet face-mask clips after 1 season of use. *J Athl Train.* 2012;47(4):428-434.

5. Swartz E, Belmore K, Decoster L, Armstrong C. Emergency face-mask removal effectiveness: A comparison of traditional and nontraditional football helmet face-mask systems. *J Athl Train.* 2010;45(6):560-569.

6. Swartz E, Boden BP, Courson R, et al. National Athletic Trainers' Association position Statement: Acute management of the cervical spine-injured athlete. *J Athl Train.* 2009;44(3):306-331.

7. Viano D, Withnall C, Halstead D. Impact performance of modern football helmets. *Ann Biomed Eng.* 2012;2012(40):160-174.