

Successful Removal of Football Helmet Face-Mask Clips After 1 Season of Use

Jason S. Scibek, PhD, ATC*; Joseph M. Gatti, MS, ATC†‡;
Jennifer I. McKenzie, MEd, ATC†‡

*Department of Athletic Training, †Department of Athletics, Duquesne University, Pittsburgh, PA; ‡University of Pittsburgh Medical Center for Sports Medicine, PA

Context: Whereas many researchers have assessed the ability to remove loop straps in traditional face-mask attachment systems after at least 1 season of use, research in which the effectiveness of the Riddell Quick Release (QR) Face Guard Attachment System clip after 1 season has been assessed is limited.

Objective: To examine the success rate of removing the QR clips after 1 season of use at the Football Championship Subdivision level. We hypothesized that 1 season of use would negatively affect the removal rate of the QR clip but repeated clip-removal trials would improve the removal rate.

Design: Retrospective, quasi-experimental design.

Setting: Controlled laboratory study.

Patients or Other Participants: Sixty-three football helmets from a National Collegiate Athletic Association Division I university located in western Pennsylvania used during the 2008 season were tested.

Intervention(s): Three certified athletic trainers (2 men, 1 woman; age = 31.3 ± 3.06 years, time certified = 9.42 ± 2.65 years) attempted to remove the QR clips from each helmet with the tool provided by the manufacturer. Helmets then were reassembled to allow each athletic trainer to attempt clip removal.

Main Outcome Measure(s): The dependent variables were total left clips removed (TCR-L), total right clips removed (TCR-R), and total clips removed (TCR). Success rate of clip removal (SRCR) also was assessed.

Results: Percentages for TCR-L, TCR-R, and TCR were 100% (189 of 189), 96.30% (182 of 189), and 98.15% (371 of 378), respectively. A paired-samples *t* test revealed a difference between TCR-R and TCR-L ($t_{188} = -2.689$, $P = .008$, $\mu_d = 0.037$, 95% confidence interval [CI] = -0.064 , -0.010). The percentage for SRCR was 96.30% ($n = 182$), whereas SRCR percentages for trials 1, 2, and 3 were 95.24% ($n = 60$), 98.41% ($n = 62$), and 95.24% ($n = 60$), respectively, and did not represent a difference ($F_{2,186} = 0.588$, $P = .56$, 95% CI = 0.94 , 0.99).

Conclusions: Our results indicated favorable and consistent success rates for QR clip removal after 1 season of use. Whereas the QR clip is an advancement in face-mask technology, continued examination of this system is required to ensure the highest level of function, allowing for effective management of the helmeted athlete.

Key Words: quick release attachment system, protective equipment, equipment removal, emergency management

Key Points

- After 1 season of collegiate football use, the Riddell Quick Release Face Guard Attachment System side clips demonstrated favorable results, with 98% of all clips being removed successfully within a clinically acceptable time frame.
- Both side clips could be removed in approximately 96% of cases, allowing for face-mask retraction.
- The removal rate did not increase over time.
- Regular equipment maintenance, refurbishment, and reconditioning must be emphasized at all levels of football.
- Athletic trainers must practice and familiarize themselves with the improvements and challenges that new equipment developments might present during potentially life-threatening situations.

Frequently, discussions of injury management involving the helmeted athlete result in some mention of maintaining spinal alignment in suspected cases of spinal cord injury and ensuring appropriate airway access. The safety of the athlete and prevention of further injury remain the focus. To this end, many investigators have examined questions related to equipment removal and cervical spine motion,^{1–3} airway access techniques,^{4,5} and techniques and efficiency of face-mask removal.^{6–13} Evidence has suggested that airway access can be obtained in the football-helmeted athletes without the removal of the face mask, ultimately reducing motion of the cervical spine

often associated with face-mask removal.^{4,5,14} However, the National Athletic Trainers' Association¹⁵ and the Inter-Association Task Force for the Appropriate Care of the Spine-Injured Athlete¹⁶ advocate full removal of the football face mask under all circumstances. Numerous tools have been examined, including the Trainer's Angel (Trainer's Angel, Riverside, CA), polyvinyl chloride cutter, anvil pruner, FM Extractor (Sports Medicine Concepts, Inc, Livonia, NY), and both manual and cordless screwdrivers. All have been described as viable methods for face-mask retraction and removal. However, the efficiency of face-mask removal and the extent to which cervical spinal

motion is generated by using these tools have been questioned considerably.^{8,9,11,13,14} Gale et al¹² and Copeland et al⁶ suggested a combined-tool approach, indicating that using a cordless screwdriver and the FM Extractor when screws fail is fast, easy, and reliable. More recently, Toler et al¹⁴ reported that access was quicker and helmet motion was less when using the Revolution IQ (Riddell Sports, Inc, Elyria, OH) helmets equipped with the Quick Release (QR) Face Guard Attachment System (Riddell Sports, Inc) than when using helmets that require removing clips with a cordless screwdriver.

Technological advances in football helmet design and construction often have occurred in response to fatalities in football and head injuries.¹⁷ Given the inherent challenges of face-mask removal, clinicians must be aware of the advancements that have occurred with respect to face-mask attachment systems.^{7,10,18} One advancement in 2002 involved a spring-loaded mechanism nut-and-bolt system that secured the face-mask clip to the helmet.⁷ Removal of the clip required a one-quarter turn with a flat-head screwdriver to release the clip from the face mask and helmet. Jenkins et al⁷ noted less time required to remove the face mask and reduced forces and torques associated with face-mask removal using this system than the FM Extractor and Trainer's Angel. In 2005, Swartz et al¹⁰ examined the time, torque, and helmet movement associated with removal of the Revolution side-slotted loop strap. When comparing different removal-tool conditions and face-mask attachment systems, they noted more cervical spine flexion and extension when attempting to remove the Revolution clip with a screwdriver. In addition, perceived exertion and time required to remove the face mask were increased when attempting removal with the FM Extractor, which was attributed to the proximity of the clip on the lateral aspect of the helmet and the shoulder pads.¹⁰ Riddell Sports, Inc, since has released the QR clip, which uses a spring-loaded mechanism and requires a special tool to depress a pin-release mechanism. In a recent study involving new, unused helmets outfitted with the QR clip, Swartz et al¹⁸ documented fast and easy face-mask release, with limited helmet motion and 100% success rate for face-mask removal. Previous researchers have made considerable efforts to assess the ability to remove loop straps in traditional T-nut and screw face-mask attachment systems after at least 1 season of use^{11,19}; unfortunately, no researchers specifically have addressed the success rate of QR clip removal after 1 season of use.

The dearth of information about routine maintenance of the QR clip is similar to that about successful clip removal after 1 season of use. Generally, investigators have suggested routinely inspecting the integrity of football helmets and face masks and observing for excessive wear and material failure (ie, cracks). Similarly, the fit of a helmet should be monitored throughout a season. Unfortunately, unless a face-mask clip becomes detached or fails during routine helmet maintenance, dysfunctional face-mask clips can go unchecked and undetected. Traditionally, helmets undergo reconditioning at the conclusion of a season. Whereas some researchers have examined the face-mask removal rates of helmets set to undergo reconditioning,^{6,19} only Gale et al¹² have examined face-mask removal during the season, noting excellent face-mask removal rates using a combined-tool approach. However, no investigators

have addressed the function of the QR clip during or at the conclusion of a football season. The literature provides no evidence to support the effect of multiple QR clip removals on function or the effects of repeated removal and reinstallation of the QR clip to ensure successful removal during an emergency. Therefore, the purpose of our study was to examine the success rate in removing the QR Face Guard Attachment System clips after 1 season of use at the Football Championship Subdivision level in the western Pennsylvania climate. We hypothesized that 1 season of use would negatively affect the removal rate of the QR clip compared with previously reported new and unused QR clip-removal rates.¹⁸ We also hypothesized that repeated trials of clip removal ultimately would improve the rate at which QR clips could be removed.

METHODS

Study Design and Helmet Sample

We used a retrospective, quasi-experimental research design and performed all data collection in a controlled laboratory environment. Revolution IQ football helmets retrofitted with the QR Face Guard Attachment System during reconditioning before the 2008 football season were used in this study. The QR replaced traditional Revolution IQ side loop straps for face-mask attachment. The QR clip consists of a spring-loaded locking-pin mechanism, which is used to secure the side loop strap to the helmet (Figure 1). To release the QR clip from the helmet, a specially designed QR Combo Installation Tool (part 27515; Riddell Sports, Inc) is used to depress the centrally located pin (Figure 2). Each helmet used a traditional Revolution IQ top loop-strap system to secure the top of the face mask to the helmet. With the side QR clips released and the traditional top loops intact, the face mask could be retracted. Retraction is not recommended during management of a helmeted athlete because of the potential for increased cervical spine motion with the face mask retracted.^{13,16} However, we sought only to examine removal



Figure 1. Revolution IQ (Riddell Sports, Inc, Elyria, OH) helmet retrofitted with Quick Release Face Guard Attachment System (Riddell Sports, Inc) clip.

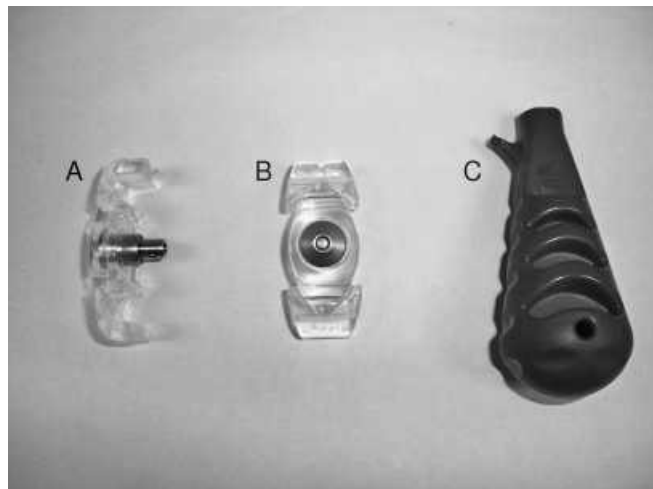


Figure 2. A, Lateral, and B, superior views of the Quick Release Face Guard Attachment System (Riddell Sports, Inc, Elyria, OH) clip, and C, the Quick Release Combo Installation Tool (part 27515; Riddell Sports, Inc).

rates associated with the QR clip alone and not to examine the entire face mask.

Our sample consisted of 63 helmets, totaling 126 QR clips (left = 63, right = 63). The distribution of the helmets worn by position is provided in the Table. Over the course of the season, the helmets were worn for 72 practices, which occurred on a synthetic field surface in western Pennsylvania, and 10 games, which took place on both grass and synthetic field surfaces in Pennsylvania (7 games), New York (1 game), Connecticut (1 game), and Rhode Island (1 game). All helmets were tested 2 days after the final game of the 2008 regular season and were scheduled to be reconditioned before the start of the 2009 football season.

Procedures

Three certified athletic trainers (2 men, 1 woman; age = 31.3 ± 3.06 years, time certified = 9.42 ± 2.65 years, hand dominance = right) from the university performed all of the helmet testing and collected all data. Two of the athletic trainers (J.M.G., J.I.M.) were responsible for the medical coverage of football at the university, and 1 (J.S.S.) was employed in the university's undergraduate athletic training education program and was involved clinically off campus. Before initiating data collection, each athletic trainer went through the same familiarization process. The athletic trainers were provided with a copy of the literature from Riddell Sports, Inc, outlining the instructions for QR clip removal and reattachment. Next, they practiced using the removal and installation tool on a new Revolution IQ helmet outfitted with new QR clips. Because 2 of the athletic trainers worked with the football program and were accustomed to the clip design, removal, and installation, the familiarization process primarily served as an opportunity for the third athletic trainer to gain familiarity with the equipment and technique required for successful clip removal and reattachment.

Data Collection

Whereas authors of many studies of this nature have used a specially fabricated helmet-stabilization device,^{6,7,11,19} we

Table. Football Helmet Distribution by Position

Position	Frequency	Helmets Tested, %
Defensive backs	14	22.22
Defensive linemen	12	19.05
Linebackers	5	7.94
Offensive linemen	12	19.05
Quarterback	1	1.58
Running backs	6	9.52
Tight ends	3	4.76
Wide receivers	5	7.94
Kickers	5	7.94
Total	63	100.00

decided that one of the athletic trainers would manually stabilize the helmet using techniques similar to actual stabilization techniques that would be performed during an emergency situation. Over the course of 3 trials, each athletic trainer stabilized the helmet once (Figure 3). Helmets were removed randomly from each athlete's locker for testing without regard for position or playing time during the season. All testing occurred in a controlled environment adjacent to the locker room that provided easy access to the locker room and was free from interruptions. Testing order for each athletic trainer was randomized by placing each individual's name on 3 separate pieces of paper, then drawing names from a container. The same randomization technique was used to determine which QR clip (right, left) would be removed first. Similarly, each athletic trainer randomly selected 1 of 8 installation tools before each trial. During each trial, the third athletic trainer monitored the testing time and recorded the number of attempts required within a trial to remove each QR clip. All helmets were tested during 1 day of data collection by each athletic trainer. To reduce the effect of fatigue on our results, each athletic trainer rested for a minimum of 3 minutes between trials. The randomized testing order resulted in multiple occurrences of greater than 3 minutes of rest for each clinician.



Figure 3. Football helmet stabilization and Quick Release Face Guard Attachment System (Riddell Sports, Inc, Elyria, OH) clip removal. Manual stabilization of the helmet was performed to mimic helmet-stabilization techniques used during an emergency situation. For clip removal, one hand was used to manipulate the tool, and the other hand provided stabilization and pulled the clip from the helmet after release of the locking-pin mechanism.

An *attempt* was defined as an instance in which the athletic trainer depressed the pin and subsequently tried to remove the clip. In addition, if the tester removed pressure from the pin or altered hand or tool placement, an attempt was recorded. *Successful clip removal* was defined as the ability to remove 1 QR clip within 15 seconds and to remove both QR clips within 30 seconds. The testing time started when the athletic trainer performing the clip removal was given the command to begin and stopped when the timer reached 30 seconds. Researchers using a spring-loaded nut-and-bolt system have suggested that 2 side-strap QR clips can be removed in 20.9 ± 9.0 seconds,⁷ whereas removal of slotted side straps and top loop straps can be performed in 53.4 ± 21.5 seconds.¹⁰ Therefore, we believed that allotting 15 seconds per clip was justified. A more recent study¹⁸ designed to investigate the same version of the QR clip we examined lent additional support to our design when the authors noted that all 4 loop straps associated with the Revolution IQ helmet, including QR clips, could be removed in 33.96 ± 14.14 seconds. Each athletic trainer started on the randomly selected side of the helmet and was instructed to perform clip removal on 1 side and then to move to the opposite side to complete the clip-removal trial. After the first athletic trainer attempted removal of the QR clips, the helmet was reassembled and the next randomly selected athletic trainer attempted removal of the clips for the same helmet. This protocol was followed 3 times to allow each athletic trainer to remove both clips from the same helmet.

Data Processing and Analysis

The variables that we assessed included total left clips removed (TCR-L), total right clips removed (TCR-R), total clips removed (TCR), and success rate of clip removal (SRCR). The *SRCR* was defined as the ability to successfully remove both QR clips within the allotted time. Success rate percentages were calculated for each condition. We also quantified the total number of attempts made using the clip-removal tool within a given clip-removal trial to garner a sense of the difficulty associated with the removal of each clip. A paired-samples *t* test was used to compare differences in removal rates for TCR-R and TCR-L. Using a 1-way analysis of variance (ANOVA), we assessed differences in SRCR with respect to testing order. We used an independent *t* test to assess differences between successful and unsuccessful clip-removal attempts, and we used the Levene test to evaluate the assumption of equal variance between these groups. An α level of .05 was set a priori. We used SPSS (version 17.0; IBM SPSS, Armonk, NY) to perform all analyses.

RESULTS

A total of 63 helmets were tested, and all helmets tested had 2 QR clips. Given that each helmet underwent testing 3 times, the total clip sample size was 378 clips (189 left clips and 189 right clips). Percentages for TCR-L, TCR-R, and TCR were 100% (189 of 189), 96.30% (182 of 189), and 98.15% (371 of 378), respectively. The paired-samples *t* test revealed a difference between TCR-R and TCR-L ($t_{188} = -2.689$, $P = .008$, $\mu_d = 0.037$, 95% confidence interval [CI] = -0.064 , -0.010). Clip-removal failures were distributed throughout the first two-thirds of all helmets

tested, and all clinicians experienced clip failures during testing, suggesting that clip-removal failures were not the result of fatigue during testing. Of the 7 clips that failed, 4 were attributed to 4 different helmets worn by offensive linemen. The remaining 3 failures were isolated to the helmet worn by 1 wide receiver.

The percentage for SRCR across all trials was 96.30% (182 of 189), whereas SRCR percentages for trials 1, 2, and 3 were 95.24% (60 of 63), 98.41% (62 of 63), and 95.24% (60 of 63), respectively. The 1-way ANOVA revealed no difference for SRCR with respect to trial ($F_{2,186} = 0.588$, $P = .56$, 95% CI = 0.94, 0.99).

The mean number of attempts required to remove the QR clips successfully was 1.06 ± 0.24 and 1.09 ± 0.33 for the left and right clips, respectively. When clip-removal failure occurred, the mean number of attempts increased to 2.67 ± 1.18 , which represented a 2.4-fold increase. The Levene test for equality of variances revealed different variances ($F = 91.06$, $P = .001$) for the means of successful and failed clip-removal attempts. An independent *t* test, assuming unequal variances, revealed differences between the mean number of attempts for successful and failed clip removal ($t_{14,19} = -5.17$, $P = .001$, 95% CI = -2.23 , -0.92).

DISCUSSION

We examined the removal rate of a new face-mask attachment system, which is designed to allow for rapid and effortless face-mask clip removal. In promotional material, Riddell Sports, Inc, claimed that the Riddell QR clip removal was 100% successful without mentioning the extent of helmet use. We were concerned with the QR's continued effectiveness after being exposed to the climate and the rigors inherent to 1 season of collegiate football use. After the collegiate football season, we successfully removed the left QR clip in all clip-removal trials, resulting in a 100% TCR-L. However, our success rate for TCR-R was 96.30%. In total, when combining the success associated with removal of both right and left clips, 98.15% were removed successfully with the installation tool alone. Anecdotally, we found that removing the left clips was easier and speculated that the combination of hand dominance and body positioning relative to the helmet might have facilitated clip-removal efforts on the left side of the helmet.

The clip-removal rates we observed are not unlike both face-mask clip and face-mask removal rates observed in the works of others. In 2005, Decoster et al¹¹ examined football face-mask removal after 1 season of use for 3 New England high schools. They noted that the screws associated with the side straps in all helmets were removed successfully 90% of the time, which was less than the screw-removal rate of the top straps (98%). They also noted that the mean time required to accomplish screw removal was 26.9 ± 5.83 seconds for all 4 loop straps.¹¹ Similarly, in 2005 Swartz et al¹⁰ noted that in 344 of 384 face-mask removal trials, 89.6% of the trials were successful. However, in 19 of 25 cutting attempts that were unsuccessful because of time, the design of the Revolution side strap and the ability to use select cutting devices might have been limiting factors.¹⁰ Gale et al¹² suggested a 98.6% face-mask removal success rate over the course of a collegiate football season, with timing of face-mask removal throughout the season

having no effect on success rate or removal time. In a study involving 600 used football helmets, Copeland et al⁶ found that using the FM Extractor or a combined approach with a screwdriver and FM Extractor for face-mask removal resulted in 99.4% and 100% success rates, respectively. Lastly, Swartz et al¹⁸ identified a 100% successful face-mask removal rate when using new, unused Revolution IQ helmets with the newest version of the pin-driven QR clip. When the QR clip was altered, examiners had to use a cutting tool to attempt clip removal, resulting in a 72.9% success rate for clip removal.¹⁸ In each of these studies,^{6,10–12,18} various clip-removal techniques were described. We believe that these exceptionally high rates associated with both new and used helmets are a testament not only to work on the part of manufacturers to design easily removable clips but also to the efforts of clinicians, investigators, and manufacturers to identify the most appropriate devices for removing face masks.

We also hypothesized that the QR clip would perform least favorably in early removal trials and would perform better in successive trials. Our rationale for this hypothesis was that the early attempts would loosen the QR pin, facilitating clip removal in subsequent trials. Looking across all trials for each athletic trainer, they successfully removed both QR clips, allowing for face-mask retraction in 182 of 189 trials, which equated to a 96.30% SRCR. However, we found no differences when looking at the ability to successfully remove both clips across trials, causing us to reject our second hypothesis. One factor that prevented us from achieving a 100% success rate was that for 1 of the 63 helmets tested, each of the athletic trainers did not successfully remove both clips because of difficulty removing the same right clip. We believe that failure of this single clip was the result of excessive wear. In the 4 other separate instances in which the right clip did not disengage, no obvious damage or excessive wear was noted. These observations are interesting and unexpected given the distribution of clip failures in relation to the helmet positions tested. Anecdotally, one would expect excessive wear to be associated with the helmet of a lineman as opposed to a wide receiver; yet this was contrary to our findings and suggests that routine maintenance might be necessary regardless of playing position. In addition, clip failures in these instances were not consistent with respect to a particular trial or clinician. Whereas some might argue that the unsuccessful clip removal in later trials was the result of faulty reinstallation, we draw attention to the fact that these failed clip removals occurred 50% of the time during the first trial of clip removal and 50% of the time during the third removal trial. However, we did note 2 trends among the clinicians during testing. First, when clip failure occurred, the clinician could not remove the clip within the allotted time or with a time extension. Second, when a clinician required multiple attempts or could not remove a clip, the other clinicians also tended to have difficulty with the respective clip. Our analysis confirmed this second observation, demonstrating that when a clip was removed successfully during all 3 trials, the average number of attempts per clip was equal to 1.06 and 1.09 for left and right clips, respectively. When failure to remove a clip occurred, the average number of attempts to remove the clip tallied 2.67 attempts. When considering the complete failure of 1 clip and the separate instances of clip

failure accompanied by subsequent clip-removal difficulty, it is likely that any instances of clip failure were the result of defective or dysfunctional clips rather than reinstallation or clinician error. Although some might question the second and third trials of clip removal as they relate to clip removal after 1 season of use, these data provide us with greater insight into the effectiveness and required maintenance of the QR clip. Our results suggest that “priming” or repeated removal and reinstallation of the QR clip does not improve either the function of or one’s ability to remove the QR clip. However, based on our findings and noted trends, we recommend routine clip-removal checks and replacement of faulty clips throughout the season to facilitate a 100% removal rate and to optimize levels of function in advance of a possible emergency.

Whereas our results appear to suggest exceptionally high success rates with respect to clip removal, we also must consider the clinical effect that our inability to remove both clips could have had in an emergency situation. Any limitation in clip removal could affect accessibility to the patient’s airway. Although we removed 98.15% of all clips, we obtained an SRCR of only 96.30%. In light of the difficulty encountered with some of the right QR clips, our accessibility and potential for face-mask removal would have been limited in a clinical situation. Given the nature of the study, it was important that testing conditions remained the same for each athletic trainer; therefore, when the helmets were reassembled between trials, the same hardware was used even if the previous rater had difficulty disengaging the mechanism. However, in a clinical situation, any difficulty associated with clip and face-mask removal warrants the immediate replacement of the face-mask clip to limit the possibility of clip failure or failure to remove the face mask (or both). We do not know to what extent regular maintenance was practiced during the football season and what effect it might have had on our overall results.

Because of our study design, we also did not know the extent to which helmet motion was generated during our attempts at QR clip removal, which again could have considerable clinical implications. As clinicians, we must be cognizant of the implications associated with difficult clip removal and the introduction of unwanted helmet and cervical spine motion during face-mask removal. Gastel et al¹ examined the cervical spine motion associated with helmet and shoulder-pad removal using a cadaveric model and provided evidence to support the level of care and caution that must be exercised when working with a helmeted athlete, particularly when the player is wearing shoulder pads. A number of researchers^{4,7–10,13,14} have assessed motion and the direction of forces being applied to the helmet and cervical spine during face-mask removal. With respect to clip cutting, some of the cutting tools seem to be more effective than others for limiting helmet and spine motion.^{4,8,9,13} However, and more importantly, the evidence clearly indicates that removal of the clips via a screwdriver results in far less motion of and force being applied to the helmet than cutting face-mask clips.^{7,10} The results for the QR clip have been favorable as they relate to head and cervical motion generated during face-mask removal.^{14,18} Ultimately, the evidence-based best practice would include a combined-tool approach, relying on a cordless screwdriver, the QR installation tool, and a cutting

device (most notably, the FM Extractor) because of the level of success associated with these tools as it relates to time required, cervical spine and head motion generated, and ease of use for the clinician.^{6,11,12,14}

Overall, our reason for conducting this study was to investigate the effectiveness of the spring-loaded, locking-pin mechanism of the QR clip. We are unsure if our success rate would have been higher if we had used the combined-tool approach that has been advocated in a number of similar studies^{6,11,12,18,19} to facilitate successful and timely face-mask removal. The time limits often associated with “successful” face-mask removal range from 30 seconds to 4 minutes and have been based on the amount of time it takes to use various face-mask removal tools under varying conditions^{4,7–9,11,12,14,18} and the time frame in which irrecoverable brain damage is likely if resuscitation does not occur and circulation is not restored.^{20,21} Considerable evidence also has been presented on speed, efficiency, and movement generated with various face-mask clip conditions and clip-removal devices.^{4–14,18} Some investigators^{4,5,14} have even studied alternatives to providing respiratory assistance with a face mask in place. Toler et al¹⁴ and Swartz et al¹⁸ identified similarities in head or helmet motion associated with face-mask removal when comparing QR-equipped face masks and face masks requiring use of a cordless screwdriver. They both noted the time required to remove face masks was less for helmets equipped with QR clips than for helmets equipped with other face-mask attachment systems.^{14,18} Toler et al¹⁴ also recently showed that the time required to provide airway assistance was less when using a pocket-mask insertion technique (approximately 20 seconds) than when removing the face mask using a cordless screwdriver (approximately 70 seconds) and when removing the face-mask QR clips (approximately 50 seconds). Furthermore, less head motion was observed with the pocket-mask insertion technique, and the difference between head and helmet motion tended to be less when using the pocket-mask insertion technique than the other face-mask removal techniques.¹⁴ Whereas the evidence supports use of the QR clip because of its ability to facilitate quick and efficient face-mask removal,^{14,18} Toler et al¹⁴ provided clinicians with an alternate method to ensuring quick and efficient airway accessibility when the QR pin mechanism failed. Regardless of the evidence, we support the recommendations of other investigators,^{10–12,14,18} cautioning athletic trainers to practice, to be prepared with alternative cutting devices, and ultimately to be familiar with the equipment that their athletes might be wearing.

We cannot draw any conclusions about whether the clip-removal success rates we observed were affected by the number of games, total number of practices, playing surfaces, or weather conditions that the equipment encountered throughout the course of the season because helmets were not tested before or throughout the season. Based on the findings of others who have studied successful face-mask removal after football helmet use after 1 season, environmental conditions seem to have little effect on these removal rates. Decoster et al¹¹ could not draw conclusions concerning the effect of weather conditions and playing surfaces on face-mask removal after 1 season of high school use. They suggested that varying types of hardware used to fasten the clips and the unprotected location of the

side clips from sweat and environmental conditions could have affected face-mask removal rates.¹¹ Although Cope-land et al⁶ engaged in a large-scale study that also involved used high school football helmets identified from 2 reconditioning facilities within the United States (1 in the Northeast and 1 in the Midwest), they could not draw any conclusions relative to environmental or use conditions. However, they noted the implications associated with varying loop-strap designs, the effect of variations in screw metallurgy, and the interaction between clip design and select cutting tools.⁶ When looking at helmets being used throughout a collegiate football season, Gale et al¹² documented no differences in removal times throughout the season or between Riddell helmet models (VSR4 and Revolution) and no relationship between face-mask removal or removal time and dry-bulb temperature or relative humidity. Although Swartz et al¹⁹ recognized differences in analyzed weather characteristics and in face-mask removal rates by region of the United States, they also noted that regional failure rates are multifactorial and might be linked more closely to hardware metallurgy, corrosion, and equipment maintenance.

The design of our study had some limitations. We did not acquire data on removal rates before the start of the season. Therefore, we could not determine what effect 1 season of use might have had on the function of QR clips and suggest an evaluation of this question in the future. As mentioned, our design did not allow us to collect data associated with other removal or cutting tools, so we could not assess what sort of effect they might have had on our overall success rates of clip removal. Whereas we attempted to simulate helmet and cervical spine stabilization during testing, the inclusion of some additional elements would have enhanced the quality of our simulated scenario. At minimum, placing a weight in the helmet to simulate the weight of the human head would have been helpful. A live model in full equipment would have been ideal. However, because of variations in the sizes of the helmets being tested, involving the actual wearers of the equipment likely would have been most appropriate to optimize the simulation, as in the work of Gale et al.¹² Last, the incorporation of a live model along with a force plate and kinematic data-collection system would have enabled us to examine the forces and cervical spine motion associated with QR clip removal after 1 season of use.

CONCLUSIONS

After 1 season of collegiate football use, the Riddell QR face-mask side clips demonstrated very favorable results, with 98% of clips being removed successfully within a clinically acceptable time frame. In addition, we noted that in approximately 96% of all cases, both side clips were removed, which allowed for face-mask retraction. We also found that this removal rate did not increase over time. When faced with potential airway or cervical spine compromise, our ability to remove face-mask clips quickly and efficiently and in a manner that minimizes helmet and cervical spine motion is paramount. Therefore, regular equipment maintenance, refurbishment, and reconditioning must continue to be emphasized at all levels of football.

Equipment manufacturers will continue to make great strides in advancing the safety and technology of helmets. As

advancements occur in the development of sports equipment, athletic trainers must continue to study the effectiveness and safety of these new technologies. We must continue to familiarize ourselves with the improvements and challenges that these new equipment developments will present during potentially life-threatening situations. Through our efforts, including the education of other allied health care professionals, we will be able to help ensure an optimal level of preparedness when addressing potentially catastrophic and life-threatening situations.

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Address correspondence to Jason S. Scibek, PhD, ATC, Department of Athletic Training, Duquesne University, 600 Forbes Avenue, 118 Health Sciences, Pittsburgh, PA 15282. Address e-mail to scibekj@duq.edu.