Characteristics of headgear release mechanisms: Safety implications

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Headgear as extraoral traction has been an important and widely used appliance in orthodontics. Its uses and effects are well documented. However, one aspect that has not been well studied is the safety of headgear use. A few reports of eye injuries caused by facebows have been published.[1-6] Though rare, the potentially high morbidity of these injuries obligates us to address the issue of headgear safety.

In response to several unpublished reports of headgear injuries, the American Association of Orthodontists issued a special bulletin to its membership in 1975.[7] The AAO was exploring headgear safety features with manufacturers and was also formulating instruction materials for patients and parents. Also responding to the growing medical and legal concerns was the California State Society of Orthodontists. In 1984, the CSSO recommended to its membership that all facebows be of a safety type and that all force mechanisms be of a breakaway type.[8]

Generally, two basic modifications have been made to the headgear appliance in order to incorporate safety: the release mechanism and the safety inner bow. The release mechanism releases the neck- or headstrap from the facebow if any excessive anteriorly directed force is placed on the facebow. In theory, this prevents the inner bow rebounding to injure the patient. The safety inner bow is designed to either prevent the facebow coming out of the tubes accidentally,[9] or to decrease the ability of the inner bow to cause injury if it does.[10,11]

Little objective testing of the release mechanisms has been done.[12] No agency sets minimal

Abstract

The risk of serious eye injury caused by a headgear appliance is a significant concern. Various safety release mechanisms have been developed in order to help prevent this type of injury, but little testing has been done. The purpose of this study was to test 18 headgear release mechanisms. Four characteristics were evaluated: force at release, extension at release, consistency of release, and performance at different rates of pull. At the point of release, mean force values ranged from 5.33 pounds to 32.83 pounds, and mean extension values ranged from 0.84 inches to 2.93 inches. Consistency was based on the percent standard deviation, and the appliances were ranked relative to each other. Nine of the 18 appliances had statistically significant differences in the two pull rates for either variable or both, but the clinical significance is uncertain. The results show a wide range of performance among the 18 appliances tested and indicate that some perform better than others.

Key Words

Headgear injury • Headgear release mechanisms • Headgear safety

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Table 1
Headgear release mechanisms tested

Code	Appliance	Type	Manufacturer
A	"A" -Company safety release module (medium)	Metal, C-clip, bilateral	"A" -Company, San Diego, Calif.
AD	Adenta safety module (600 grams)	Metal, C-clip, bilateral	ADENTA GmbH, Gilching, Germany
EQ	Equa-Pull module (heavy)	Metal, "constant force," bilateral	Dr. Roger Wolk, Malibu, Calif.
FS	Freedom safety latch	Plastic, no force delivery, glued to outerbow, bilateral	NOLA Specialities Inc., Covington, La.
GB	GAC blue safety module	Plastic, bilateral	GAC International, Inc., Central Islip, NY
GS	Sof Gear breakaway module	Plastic, C-clip, bilateral	GAC International, Inc.
NC	NewGear Cervical Headgear (medium)	Plastic, strap part of device, unilateral	Ortho Kinetics Corp., Vista, Calif.
NH	NewGear High Pull force module (medium)	Plastic, bilateral	Ortho Kinetics Corp.
NW	NorthWest Snap-Way cervical force module (10-22 oz)	Metal, bilateral	3M Unitek, Monrovia, Calif.
OC	Ormco C-type release module (heavy)	Plastic, C-clip, bilateral	Ormco Corp., Orange, Calif.
OR	Ormco release module (heavy)	Plastic, bilateral	Ormco Corp.
OS	Ormco Sentry Headgear System	Plastic, strap part of device, bilateral	Ormco Corp.
OO	Ortho Organizers safety system release module	Plastic, C-clip, bilateral	Ortho Organizers, Inc., San Marcos, Calif.
OB	Ortho-Latch Break-Away module (with 24-36 oz elastic band)	Plastic, no force delivery, bilateral	Orthoband Company, Inc, Barnhart, Mo.
PZ	Pozzi safety module (medium)	Plastic, C-clip, bilateral	Pozzi Orthodontics, Tolleson, Ariz.
3MC	3M Unitek Traction release cervical module (medium)	Plastic, C-clip, bilateral	3M Unitek
3MH	3M Unitek Traction release high-pull module (medium)	Plastic, bilateral	3M Unitek
TP	TP safety module	Plastic, C-clip, bilateral	TP Orthodontics, Inc., LaPorte, Ind.

acceptable standards for their use or monitors their manufacture and performance. No definition of clinical or legal safety has been formulated, and in fact, no law even requires that a safety release mechanism be used. These factors make the paucity of testing more understandable, but they do not eliminate the need for it.

The purpose of this project was to evaluate the performance of various commercially available safety release mechanisms. The reliability of these mechanisms to release at different rates of pull was tested, and the extension and force of activation were measured.

Materials and methods

Eighteen headgear release mechanisms, representing a variety of appliances and encompassing a large majority of those in current use in the United States, were selected for study. Five each of the 18 mechanisms were tested as part of a

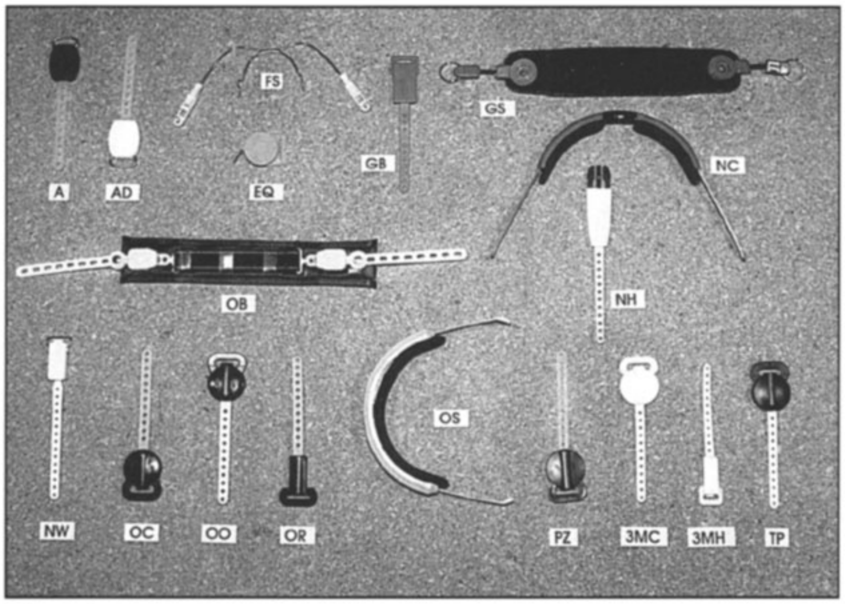

Figure 1

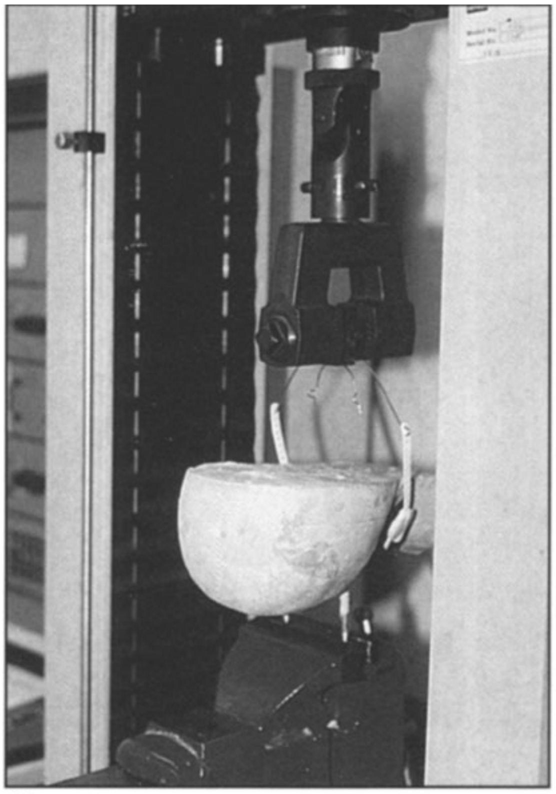

Figure 2

Figure 1
Eighteen headgear release mechanisms studied

Figure 2
Testing setup on the Instron machine

complete headgear system: a facebow (Series 5, size 3, 3M Unitek, Monrovia, Calif), a neckstrap, and the release mechanisms (Table 1 and Figure 1). Every effort was made to standardize the testing; however, some differences existed. All but two of the appliances included both a release mechanism and a force mechanism (coil spring, elastic, etc.). FS and OB are solely release mechanisms, so a means of force delivery must be added to the system. FS was tested without adding the means of force because there is no standard type or size used. OB was tested with the elastic strap with which it is normally sold. Also, by necessity, GS, NC, and OS were tested with their own neckstraps.

A life-size head and neck model made of yellow stone was rigidly fixated to an Instron machine, model 1122 (Instron, Canton, Mass). The headgear system was placed around the head and neck, with the facebow attached to the Instron at the most anterior part of the inner bow (Figure 2). Each test began with a baseline load of one pound, in order to take the slack out of the system and to standardize the testing. The Instron then activated the appliance until the headgear released. All tests were performed using an anteriorly directed pull on the facebow. The Instron recorded the force in pounds at release. A digital stopwatch recorded the time in seconds from start to release; this data was then converted to distance the facebow traveled, or extension, in inches. The appliances were tested at two different rates of pull: 5 inches per minute and 50 inches per minute. Each sample was tested five times at each rate of pull.

A components of variance analysis was performed for both force and extension at 5 and 50 inches per minute for each appliance. This was done in order to determine the absolute and relative between- and within-sample contribution to the total variation around the mean. A paired *t*-test also was performed to determine whether statistically significant differences existed between the pull rates of 5 inches per minute and 50 inches per minute for the force and extension variables.

Results

Descriptive statistics for each of the 18 appliances tested are presented in Tables 2 to 5. Table 2 displays the values for the extension variable at 5 inches per minute and Table 3 shows them at 50 inches per minute. Table 4 displays the values for the force variable at 5 inches per minute and Table 5 shows them at 50 inches per minute.

The extension means for both rates of pull are plotted in Figure 3. They range from 0.86 to 2.93 inches at 5 in/min and from 0.84 to 2.63 inches at 50 in/min. For both rates of pull, only the EQ appliance had a mean above 2.5 inches. Four appliances had means below 1.5 inches: 3MH, FS, NH, and OB. The means of all the other appliances were between 1.5 and 2.5 inches.

The force means for both rates of pull are plotted in Figure 4. They range from 5.46 to 32.83 pounds at 5 in/min and from 5.33 to 30.69

Table 2
Statistics for extension variable at 5 in/min

	Mean (inches)	SD (inches)	SD/ mean %	Variance (inches squared) between	Variance (inches squared) within	R-square
3MC	2.28	0.13	5.7	0.017	0.001	0.95
3MH	1.06	0.12	11.3	0.006	0.008	0.46
A	1.85	0.07	3.8	0.000	0.005	0.03
AD	2.01	0.17	8.5	0.024	0.005	0.84
EQ	2.93	0.32	10.9	0.089	0.015	0.86
FS	0.86	0.21	24.7	0.039	0.003	0.93
GB	2.27	0.16	7.0	0.017	0.009	0.64
GS	2.31	0.13	5.6	0.017	0.001	0.93
NC	2.01	0.29	14.4	0.068	0.019	0.78
NH	1.36	0.20	14.7	0.021	0.021	0.50
NW	1.67	0.12	7.2	0.008	0.005	0.59
OB	1.21	0.52	43.0	0.053	0.222	0.19
OC	2.24	0.20	8.9	0.012	0.026	0.31
OO	2.30	0.11	4.8	0.004	0.009	0.29
OR	1.63	0.07	4.3	0.001	0.004	0.28
OS	1.82	0.04	2.2	0.000	0.002	0.01
PZ	1.86	0.06	3.2	0.002	0.001	0.63
TP	2.29	0.31	13.5	0.092	0.006	0.94

Table 3
Statistics for extension variable at 50 in/min

	Mean (inches)	SD (inches)	SD/ mean %	Variance (inches squared) between	Variance (inches squared) within	R-square
3MC	2.03	0.09	4.4	0.006	0.002	0.73
3MH	0.97	0.08	8.2	0.005	0.002	0.72
A	1.97	0.06	3.0	0.001	0.003	0.32
AD	1.97	0.16	8.1	0.024	0.003	0.88
EQ	2.63	0.49	18.6	0.213	0.029	0.88
FS	0.84	0.22	26.2	0.049	0.001	0.98
GB	2.24	0.20	8.9	0.032	0.007	0.82
GS	2.22	0.12	5.4	0.013	0.001	0.90
NC	1.67	0.07	4.2	0.004	0.000	0.90
NH	1.31	0.21	16.0	0.043	0.003	0.94
NW	1.75	0.07	4.0	0.001	0.004	0.20
OB	1.22	0.46	37.7	0.086	0.123	0.41
OC	2.00	0.08	4.0	0.003	0.004	0.45
OO	2.24	0.11	4.9	0.002	0.011	0.16
OR	1.72	0.09	5.2	0.000	0.009	0.01
OS	1.78	0.05	2.8	0.000	0.002	0.11
PZ	1.61	0.06	3.7	0.001	0.002	0.46
TP	2.35	0.35	14.9	0.119	0.004	0.97

pounds at 50 in/min. Only the NC appliance had mean values in excess of 30 pounds for both rates. Two appliances—OC and OS—had means between 20 and 30 pounds, but each only at 5 in/min. The mean force values of four appliances were below 10 pounds: 3MH, EQ, OB, and OR. All other mean values were between 10 and 20 pounds.

Tables 6 (extension) and 7 (force) show the mean values at 5 and 50 in/min, the mean differences, and the standard error of the differences, and give the corresponding *t*- and *p*- values. At a significance level of $p<0.05$, six appliances had statistically significant different mean values at 5 and 50 in/min for the force variable: 3MC, A, GS, NH, OC, and PZ. Eight appliances had statistically significant differences for the extension variable: 3MH, 3MC, A, EQ, GS, OC, OS, and PZ. Of those at $p<0.05$, only appliance A had a mean value that was greater at 50 in/min than at 5 in/min.

Figure 5 graphs the standard deviations as a percentage of the means of each appliance for the extension variable. At 5 inches per minute, the percent standard deviation was less than 5% for five appliances: OS, PZ, A, OR, and OO. The value was between 5% and 10% for six appliances: GS, 3MC, GB, NW, AD, and OC. The percent standard deviation was between 10% and 15% for five appliances: EQ, 3MH, TP, NC, and NH. The value exceeded 15% for two appliances: FS and OB.

For extension at 50 inches per minute, the percent standard deviation was less than 5% for eight appliances: OS, A, PZ, NW, OC, NC, 3MC, and OO. The value was between 5% and 10% for five appliances: OR, GS, AD, 3MH, and GB. The percent standard deviation was between 10% and 15% for the TP appliance, and it exceeded 15% for four appliances: NH, EQ, FS, and OB.

Figure 6 graphs the standard deviations as a percentage of the means of each appliance for the force variable. At 5 inches per minute, the percent standard deviation was less than 5% for two appliances: NC and PZ. The value was between 5% and 10% for eleven appliances: 3MC, EQ, A, GS, OS, GB, NH, 3MH, OR, OC, and OO. The percent standard deviation was between 10% and 15% for three appliances: AD, OB, and TP, and it exceeded 15% for two appliances: NW and FS.

For force at 50 inches per minute, the percent standard deviation was less than 5% for five appliances: PZ, 3MC, NC, OC, and A. The value was between 5% and 10% for six appliances: GS, OS, EQ, NH, OO, and 3MH. The percent standard deviation was between 10% and 15% for four appliances: OR, NW, OB, and AD, and it exceeded 15% for three appliances: GB, TP, and FS.

Between-sample variance is a measure of the variation in performance from device to device in a given appliance. Within-sample variance is a measure of the variation in performance from test to test in a given device. The *R*-square value is a ratio of the between sample variance to the total variance and indicates what proportion of the total variation is attributed to between-sample variation. Total variance is simply the sum of between-sample and within-sample variance. For example, Table 2 shows that 3MC has an R-square value of 0.95. This means that 95% of the total variation in the performance of 3MC (for extension at 5 in/min) is due to between-sample variation and the remaining 5% is due to within-sample variation.

Discussion

With regard to safety, the ideal release mechanism would have at least three features:

Extension—It would release before the inner bow ends exit the headgear tubes or, at a minimum, before the inner bow ends exit the oral cavity. The inner bow ends cannot injure the eye if they never leave the mouth.

Force—It would release at a force above its therapeutic level and above levels attained during normal waketime and sleeptime activity, but below the force levels related to improper disassembly.

Consistency—Its release point would have little variation, both in the repeated performance of an individual device (within-sample variation), and in the performance from device to device (between-sample variation).

These criteria are vague, especially for force and extension, but setting a safety standard is an arbitrary and difficult task and has not been undertaken previously. For example, an absolute standard for extension is almost impossible because of anatomical variation between patients and because the distance from tube to outside the oral cavity is not a fixed distance on any single patient. In general, though, the shorter the extension release point, the less likely it is for the inner bow ends to exit the oral cavity. The discussion of the results will thus evaluate the appliances relative to the performance of the other appliances.

Even without an absolute safety standard for extension, the appliances can be rated for the extension characteristic based on the probability that the shorter the extension release point, the less likely it is for the inner bow ends to exit the oral cavity. The performance of the appliances from shortest extension to longest are as follows: FS, 3MH, OB, NH, OR, NW, PZ, OS, NC, A, AD, OC, 3MC, GB, GS, OO, TP, and EQ. Of the four appliances that had mean values below 1.5 inches, 3MH and NH were designed specifically for use with a high-pull appliance. FS had the shortest mean extension, but as noted earlier, the FS sample did not include any elastics in the tested system, thus its mean extension value is deceptively low. Elastics added by the clinician would, of course, significantly increase the extension release point. EQ was the only appliance with a mean value above 2.5 inches; however, the manufacturer claims that it is a "constant force" appliance. As such, it can and should be adjusted not based on force level like the others, but based on the amount of extension, thus the mean ex-

Table 4
Statistics for force variable at 5 in/min

	Mean (inches)	SD (inches)	SD/ mean %	Variance (inches squared) between	Variance (inches squared) within	R-square
3MC	15.15	0.91	6.0	0.700	0.120	0.85
3MH	8.50	0.77	9.1	0.471	0.118	0.80
A	15.65	1.12	7.2	0.318	0.939	0.25
AD	12.75	1.31	10.3	1.257	0.454	0.73
EQ	5.46	0.39	7.1	0.124	0.032	0.79
FS	12.02	4.57	38.0	20.260	0.585	0.97
GB	17.88	1.51	8.4	1.324	0.959	0.58
GS	14.22	1.12	7.9	0.771	0.480	0.62
NC	32.83	1.37	4.2	0.021	1.854	0.01
NH	13.24	1.13	8.5	0.960	0.328	0.75
NW	16.46	2.74	16.6	2.848	4.657	0.38
OB	6.30	0.75	11.9	0.153	0.417	0.27
OC	22.16	2.21	10.0	0.697	4.190	0.14
OO	17.38	1.74	10.0	1.995	1.017	0.66
OR	9.26	0.84	9.1	0.277	0.435	0.39
OS	20.88	1.73	8.3	0.781	2.209	0.26
PZ	12.93	0.57	4.4	0.157	0.172	0.48
TP	17.93	2.68	14.9	7.028	0.179	0.98

Table 5
Statistics for force variable at 50 in/min

	Mean (inches)	SD (inches)	SD/ mean %	Variance (inches squared) between	Variance (inches squared) within	R-square
3MC	13.24	0.41	3.1	0.142	0.025	0.85
3MH	8.25	0.78	9.5	0.421	0.186	0.69
A	18.43	0.88	4.8	0.565	0.215	0.72
AD	11.61	1.62	14.0	1.721	0.889	0.66
EQ	5.33	0.45	8.4	0.181	0.018	0.91
FS	11.31	4.33	38.3	18.536	0.187	0.99
GB	17.45	3.02	17.3	8.139	0.978	0.89
GS	13.78	1.11	8.1	1.054	0.186	0.85
NC	30.69	1.15	3.7	0.912	0.411	0.69
NH	12.29	1.07	8.7	0.945	0.206	0.82
NW	16.69	1.89	11.3	0.634	2.920	0.18
OB	5.93	0.81	13.7	0.294	0.363	0.45
OC	16.69	0.72	4.3	0.105	0.413	0.20
OO	16.78	1.50	8.9	1.163	1.091	0.52
OR	9.44	1.03	10.9	0.191	0.870	0.18
OS	19.79	1.64	8.3	2.027	0.674	0.75
PZ	10.30	0.27	2.6	0.052	0.020	0.73
TP	17.76	3.60	20.3	12.753	0.207	0.98

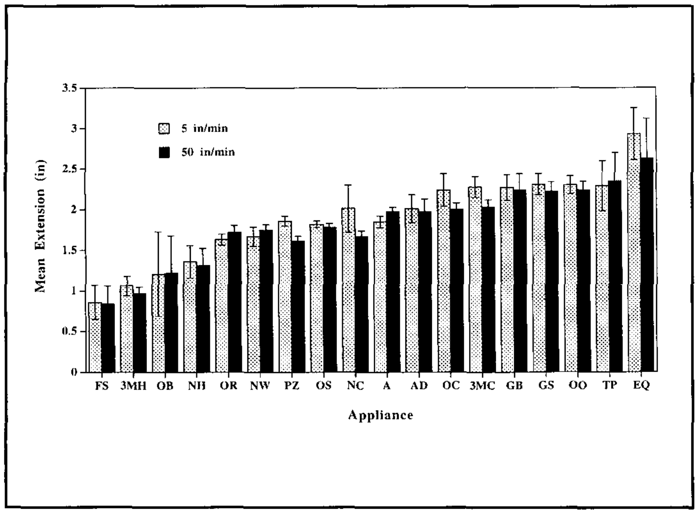

Figure 3

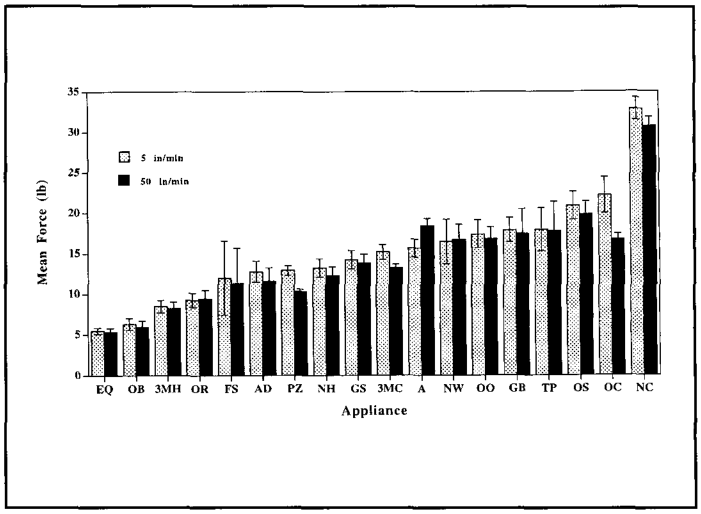

Figure 4

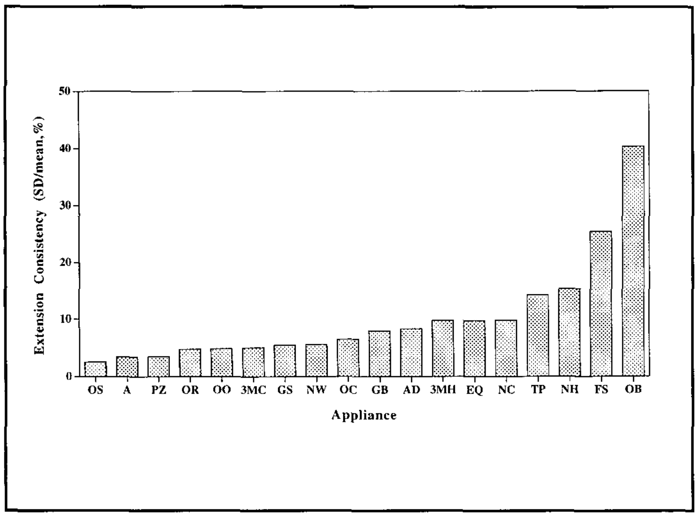

Figure 5

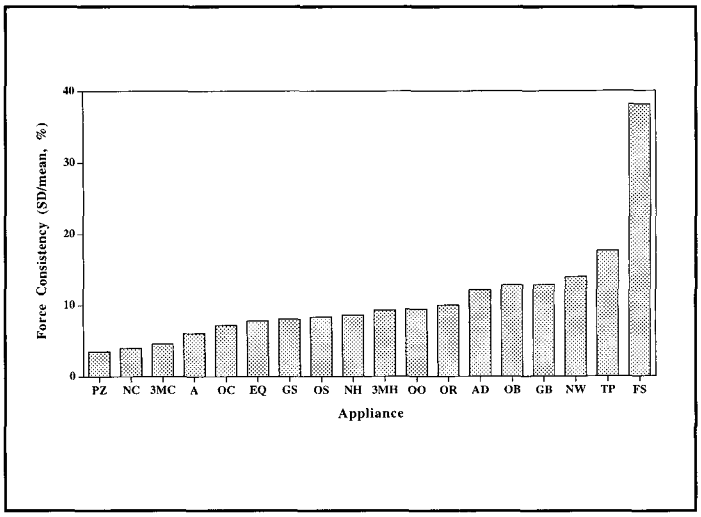

Figure 6

Figure 3
Mean extension values (in inches) for each appliance at both rates of pull

Figure 4
Mean force values (in pounds) for each appliance at both rates of pull

Figure 5
Percent standard deviations of each appliance for the extension variable

Figure 6
Percent standard deviation of each appliance for the force variable

tension value for EQ is misleading. The manufacturer recommends that EQ be attached to the neckstrap at 3/4 of its total extension.

When examining force means, the majority of appliances released at levels between 10 and 20 pounds. It is difficult to say whether these force levels are "safe," but they are generally much higher than the values claimed by the manufacturers. The appliances cannot be rated easily for the force characteristic, in part because the same probability does not hold true for force as it does for extension. Having a lower force at release does not necessarily mean that the inner bow is less likely to exit the oral cavity. Thus, extension seems to be a more important feature than force in regard to safety. One appliance, NC, had force means far higher than the others at both rates of pull. NC is unique in that it has one release mechanism located directly at the back of the neck. All other appliances have two release mechanisms, one on either side of the neck, attached to the outer bow ends. Because of its design, an anteriorly directed force on a facebow is perpendicular to the release mechanism rather than parallel like the others, necessitating a higher force to release. In fact, three of the five NC appliances broke before they released during testing. The statistics for NC, thus, are derived from only two appliances.

Consistency was evaluated by examining the standard deviation as a percentage of the mean for force and extension at both rates of pull for each appliance. The relative performances of the appliances from most consistent to least consistent for extension were as follows: OS, A, PZ, OR, OO, 3MC, GS, NW, OC, GB, AD, 3MH, EQ, NC, TP, NH, FS, and OB (Figure 5). For force, the relative performances from most to least consistent were: PZ, NC, 3MC, A, OC, EQ, GS, OS, NH, 3MH, OO, OR, AD, OB, GB, NW, TP, and FS (Figure 6). While consistency is best evaluated by the percent standard deviation, the components of variance analysis allows an interesting view of the cause of inconsistency by looking at the *R*-square values. These values indicate relative contributions to the total variation and are most meaningful with appliances that have a large total variation or percent standard deviation. For example, the *R*-square values show that of the three appliances with the least consistency, the differences from device to device (between-sample variation) were the major cause of that inconsistency in FS and TP. Conversely, the primary cause of OB's poor consistency was the differences from test to test in a single device (within-sample variation).

The objective of using two rates of pull was to simulate differing conditions in which the facebow is removed or the appliance activated, and then to determine whether there were significant differences in performance. The rate of 5 in/min was chosen to simulate normal waketime and sleeptime activity. The rate of 50 in/min simulated improper facebow removal or perhaps disengagement due to an accident. Other conditions, such as an abrupt yank by another person, could result in pull rates as much as ten times the fastest rate tested here. Having the two tested rates differ by a magnitude of 10, however, meant significant differences could be seen, and makes prediction of performance at other rates possible. While the appliances might perform differently at a much faster rate, the data do not lead to that conclusion. Of the 18 appliances tested, only six had statistically significant different means for the force variable, while eight did for the extension variable, where $p<0.05$. The issue of clinical versus statistical significance must also be addressed. When looking at those appliances that have statistically significant different means for the force variable, the means in each case so far exceed therapeutic levels that the clinical significance becomes negligible. For the extension variable, however, clinical significance is difficult to determine. Without a safety standard on which to base that determination, the statistically significant differences exhibited may or may not be clinically significant.

The testing of the release mechanisms within a complete headgear system provided a realistic picture of their actions. The amount of extension measured included the extension of the entire system: neckstrap, facebow, and release mechanisms. In the only other published testing of release mechanisms, Postlewaite[12] made measurements on single release mechanisms.

This study should allow the clinician to evaluate the performance of a preferred release mechanism and compare it with others, to better understand the safety aspects of the mechanism and of the headgear appliance in general and to make the appliance and its use as safe as possible. This study of release mechanisms focused solely on potential safety, and the evaluation and rating of the various appliances did not consider their clinical effectiveness, ease of use, esthetic value, etc. Obviously the clinician must consider all these factors when choosing a release mechanism

Table 6
Comparison of extension variable at 5 in/min and 50 in/min

	Mean 5 in/min	Mean 50 in/min	Mean difference (inches)	SE difference	*t*	*p*-value
3MC	2.28	2.03	0.25	0.04	6.25	0.003
3MH	1.06	0.97	0.10	0.01	10.52	0.000
A	1.85	1.97	-0.13	0.03	-4.84	0.008
AD	2.01	1.97	0.04	0.03	1.48	0.214
EQ	2.93	2.63	0.29	0.08	3.60	0.023
FS	0.86	0.84	0.02	0.02	1.20	0.295
GB	2.27	2.24	0.03	0.04	0.63	0.566
GS	2.31	2.22	0.08	0.01	7.21	0.002
NC	2.01	1.67	0.14	0.05	2.88	0.213
NH	1.36	1.31	0.05	0.08	0.56	0.602
NW	1.67	1.75	-0.08	0.05	-1.61	0.183
OB	1.21	1.22	-0.01	0.15	-0.05	0.964
OC	2.24	2.00	0.24	0.04	5.51	0.005
OO	2.30	2.24	0.06	0.02	2.75	0.052
OR	1.63	1.72	-0.09	0.04	-2.38	0.076
OS	1.82	1.78	0.05	0.01	7.51	0.002
PZ	1.86	1.61	0.25	0.02	11.11	0.000
TP	2.29	2.35	-0.05	0.10	-0.56	0.608

Table 7
Comparison of force variable at 5 in/min and 50 in/min

	Mean 5 in/min	Mean 50 in/min	Mean difference (pounds)	SE difference	*t*	*p*-value
3MC	15.15	13.24	1.92	0.21	8.91	0.001
3MH	8.50	8.25	0.26	0.22	1.16	0.312
A	15.65	18.43	-2.78	0.60	-4.61	0.010
AD	12.75	11.61	1.14	0.56	2.02	0.113
EQ	5.46	5.33	0.13	0.08	1.60	0.184
FS	12.02	11.31	0.70	0.26	2.75	0.051
GB	17.88	17.45	0.44	0.85	0.51	0.637
GS	14.22	13.78	0.44	0.11	4.09	0.015
NC	32.83	30.69	2.61	1.77	1.47	0.379
NH	13.24	12.29	0.95	0.31	3.06	0.038
NW	16.46	16.69	-0.22	1.06	-0.21	0.843
OB	6.30	5.93	0.37	0.17	2.21	0.091
OC	22.16	16.69	5.47	0.69	7.91	0.001
OO	17.38	16.78	0.60	0.23	2.54	0.064
OR	9.26	9.44	-0.19	0.50	-0.38	0.725
OS	20.88	19.79	1.09	0.44	2.49	0.067
PZ	12.93	10.30	2.63	0.14	19.20	0.000
TP	17.93	17.76	0.16	0.72	0.23	0.831

and other components of a headgear appliance.

Several avenues for further study exist. It would be useful to test the release mechanisms at a very high rate of pull, which we were unable to do with the Instron machine. Also, all the testing was done using an anteriorly directed pull on the facebow. The performance of the mechanisms when subjected to a nonaxial pull is not known. Finally, studying the decay rate of the mechanisms could be helpful. The effect of time and use on the mechanisms is not known. This is more of a factor with some appliances than others. For example, with NC the release mechanism is also the means of attachment and detachment of the headgear appliance, thus it is stressed more often than most. The majority of the other appliances attach and detach separately from the release mechanisms.

Conclusions

This study tested various headgear release mechanisms and evaluated three characteristics—extension, force, and consistency—at two rates of pull. The mechanisms showed few differences in performance at the two rates of pull, which differed by a magnitude of ten. Based on this study, the two most important characteristics for safety are the extension at release and the consistency of release. A mechanism with a short extension release point and high consistency is desirable. The 18 appliances are ranked in both these categories according to their performance. The appliances that displayed the best combination of these two characteristics were: PZ, OS, A, and 3MH.

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