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HARD-COATED POLYCARBONATE VERSUS CR-39 LENSES: A Field Study

J. W. Miller
Wayne F. Provines, Lieutenant Colonel, USAF, BSC
Alton J. Rahe, M.S.
Roger H. Blevins, Staff Sergeant, USAF
Thomas J. Tredici, Colonel, USAF, MC

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USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, TX 78235-5301

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

J. W. MILLER
Project Scientist

THOMAS J. TREDICI, Colonel, USAF, MC
Supervisor

ROYCE MOSER, Jr.
Colonel, USAF, MC
Commander

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The surface abrasion characteristics of 109 pair of spectacle lenses were evaluated after 1 yr of wear at Nellis AFB, Nevada. One lens of each pair was an abrasion-resistant coated Lexan while the other was uncoated CR-39. Data showed that the hard-coated Lexan lenses are more abrasion-resistant than uncoated CR-39 lenses.

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HARD-COATED POLYCARBONATE VERSUS CR-39 LENSES: A FIELD STUDY

INTRODUCTION

In recent wars the percentage of wartime ocular injuries, when compared to all other wounds, has increased greatly. From near the turn of the century through the Korean War, ocular injuries remained constant at about 2.5% of the total injuries (1). Reports from the more recent Southeast Asia and the Middle East conflicts indicate the number of eye injuries has risen to about 6% (2). Currently, all prescription lenses issued to military personnel are either heat-treated glass or CR-39 plastic. While these lenses are classified by the Federal Drug Administration as "impact resistant," it is well recognized that they are neither unbreakable nor shatterproof. Polycarbonate (Lexan) plastic demonstrates a tremendous capability to withstand the impact of high-speed objects (3). Even though polycarbonate plastic has very poor abrasion resistance, it has been successfully used for industrial eye protection and in aircrew helmet visors. The soft properties of polycarbonate preclude standard grinding and polishing techniques in the fabrication of prescription polycarbonate lenses. Several companies have recently developed alternate methods for producing prescription polycarbonate lenses. All polycarbonate lenses used in this study were purchased from the Gentex Corporation. A direct comparison field-use study of CR-39 prescription lenses-vs-polycarbonate prescription lenses was completed in 1979 (4). While the optical properties of polycarbonate were found to be comparable to other lens materials, these lenses--even with a hard coating--did not possess the abrasion resistance to be acceptable for routine use. Nevertheless, from these data, polycarbonate was recommended for issue to combat personnel. Shortly after the test was published, a polycarbonate ophthalmic lens manufacturer reported to us an improvement in hard coating state-of-the-art. Their data indicated that coated polycarbonate lenses processed with a copolymer coating gave equal or better abrasion resistance than the uncoated CR-39. While skeptical of those reports, we nevertheless conducted preliminary laboratory abrasion tests using steel wool as an abrader. The results were quite favorable for the coated polycarbonate lenses. In the past, poor correlation between laboratory and field tests has been found for coated lens performance (5). Even so, because of these preliminary laboratory tests, the manufacturer's data and the need for a superior eye protection material, we believed a field-use test was in order.

PROCEDURE AND FINDINGS

Nellis Air Force Base, Nevada, was chosen as the test base. The dusty environment had, on previous occasions, provided a severe field environment test for lens durability performance (6). Optometry Clinic personnel support was obtained by request at the Nellis Hospital. Four months prior to initiating the test, the Nellis optometrist began a list of patients seen for routine refractions who would volunteer as participants. Dispersal of 152 pair of prescription lenses mounted in metal flight frames (HGU-4/P) was made. One lens of each pair was an abrasion-resistant coated polycarbonate lens while the other was uncoated CR-39. The polycarbonate lens was randomly placed in the right or left side of the spectacle. The participants were told only that the lenses were nonstandard, but they were to treat them as ordinary glasses.

Lens examination and subjective durability scoring were made, by a registered research optician, at 4- and 12-month intervals from the initial dispensing. An 8-month evaluation was planned; however, the optician's evaluation was cancelled due to his illness. A durability score of 0 = no observed scratching; 1 = a few superficial scratches; 2 and 3 = successive severity of number and penetration of scratches. While scoring the lenses, the optician had no record of polycarbonate lens placement (right side, left side). The optician's 4-month lens score records were purposely not available during the 12-month on-site evaluation. Additionally, the participants were asked to complete an evaluation form, shown in Figure 1.

NAME: _____ RANK: _____

DUTY PHONE: _____ HOME PHONE: _____

1. Did you wear the glasses all the time? YES _____ NO _____ If NO, did you wear the glasses: MOST OF THE TIME _____ HARDLY AT ALL _____

   Please explain _____

2. Were the glasses comfortable? YES _____ NO _____ If NO, indicate the problem _____

3. Is either of your lenses scratched or marred? YES _____ NO _____ If YES, which one? RIGHT _____ LEFT _____ BOTH _____ If both, which is worse? RIGHT _____ LEFT _____ Did any unusual event contribute to the lens damage? YES _____ NO _____ If YES, please explain _____

4. To what extent does the scratch or mar interfere with your vision?

   A GREAT DEAL _____ SOME _____ NOT AT ALL _____

5. Were there any unusual experiences noticed with spectacle wear?

   YES _____ NO _____ If YES, please explain _____

6. How do you usually clean your lenses?

   HANDKERCHIEF _____ WET _____ DRY _____

   KLEENEX _____ WET _____ DRY _____

   PAPER TOWEL _____ WET _____ DRY _____

   OTHER (Please Explain) _____ WET _____ DRY _____

7. Do you think that the lenses used in the test should be considered for standard military spectacles? RIGHT LENS: YES _____ NO _____

   LEFT LENS: YES _____ NO _____

COMMENTS: _____

Figure 1. Questionnaire for users' evaluation of lenses.

The participants were told that lenses would be replaced should lens deterioration become unacceptable for wear. If this occurred, treated glass lenses were to be used and the participant would be discontinued from the study.

One week prior to lens-evaluation dates, postcards were mailed to the participants requesting them to bring their glasses to the Nellis Optometry Clinic. A notice of evaluation dates was placed in the Nellis Base Bulletin. The response rates were: 4 months, 77% (117/152), and 12 months, 89% (97/109). During the study a total of 43 participants asked for new lenses. Data from their test spectacle lenses are included in the analysis. No effort was made to assess the cause of additional subject loss. Previous field studies indicated loss due primarily to military transfer.

Table 1 presents the summary of the optician's abrasion scores for each spectacle pair of lenses at the 12-month evaluation. For example, 10 pair of spectacles showed a CR-39 durability score of 1, and a polycarbonate score of 0. The optician recorded the same score for both lenses on 50 pair of spectacles (Diagonal Data: 14 + 8 + 14 + 14). On 32 of the remaining 47 pair, the score was worse for the CR-39 than the polycarbonate ($p < .05$). These data were generally in agreement with the 4-month data (Table 2), where the polycarbonate lenses were also reported as less abraded than the CR-39 ($p < .01$).

TABLE 1. OPTICIAN'S SCORE FOR EACH CR-39 AND POLYCARBONATE LENS PAIR ON 97 SUBJECTS

(12-month evaluation)

		CR-39 lens score			
		0	1	2	3
Polycarbonate lens score	0	14	10	4	2
	1	4	8	7	5
	2	4	6	14	4
	3	1	0	0	14

NOTES:

1. CR-39 mean score: 1.54
2. Polycarbonate mean score: 1.29

TABLE 2. OPTICIAN'S SCORE FOR EACH CR-39 AND POLYCARBONATE LENS PAIR ON 115 SUBJECTS*

(4-month evaluation)

		CR-39 lens score			
		0	1	2	3
Polycarbonate lens score	0	27	15	6	0
	1	9	23	7	5
	2	0	5	8	5
	3	0	3	1	1

* Data incomplete on 2 subjects

NOTES:

1. CR-39 mean score: 1.07
2. Polycarbonate mean score: .83
3. Based on the assumption that the difference between the scores represents equal increments of severity of scratching.

In order to measure the accuracy of the optician's scoring one would need independent repeated scorings on the same lens under identical conditions. Since these data were not available, it was decided to check on the consistency of the optician's scoring by comparing abrasion scores between the 12-month and the 4-month evaluations. One would expect the lens to get worse over time (greater scores) or at best stay the same. Any "improvement" over time (small scores) can be thought of as an error in scoring. The comparison of the abrasion scores between the 4- and 12-month evaluations for polycarbonate and CR-39 separately is given in Table 3. Identical scores were recorded for 33 polycarbonate lenses (Diagonal Data). Only 6 polycarbonate lens scores (4 + 1 + 1) out of 78 lenses showed "improvement" (less scratching at 12 months than at 4 months). Of the CR-39 lens scores, 30 lenses were scored identical while 10 (6 + 1 + 3) of 79 showed "improvement" by 1 score only. These results indicated that the optician's scoring criteria were consistent. Remember that in Table 3, no comparison was made between CR-39 and polycarbonate lenses, only between 12- and 4-month data of the same lenses.

TABLE 3. CONSISTENCY CHECK ON OPTICIAN'S SCORES

(4-month vs 12-month evaluation)

	Polycarbonate					CR-39				
		4-month scores					4-month scores			
		0	1	2	3		0	1	2	3
12-month scores	0	18	4	1	1	0	11	6	0	0
	1	10	10	0	0	1	9	10	1	3
	2	4	12	4	0	2	3	7	6	3
	3	2	4	7	1	3	3	7	10	3
		Total: 78*					Total: 79			

* Data missing for one subject

The lenses with the worst abrasion, as reported on question 3 of the participants' subjective questionnaire (Fig. 1), were compared to the polycarbonate lenses, as shown in Table 4. Only 18 of 60 times was polycarbonate chosen by subjects to be the worst lens ($p < .01$). This finding was consistent with the results of the other 2 evaluations.

TABLE 4. QUESTION 3: LENS WITH WORSE SCRATCHING COMPARED TO POLYCARBONATE LENS ON 60 SUBJECTS

(12-month evaluation)

		Worst lens	
		Right	Left
Polycarbonate lens	Right	5	21
	Left	21	13

Explanation for incomplete data:

29 reported no scratching

5 reported both lenses scratched, but never reported which lens was worse

1 reported scratching, but did not give any location

2 missing data

37 + 60 above = total of 97 evaluated at 12 months

The responses to question 7 were analyzed in the same manner as the optician's scores. The results are displayed in Table 5. The diagonal data (59 and 4) do not aid in deciding the preference for CR-39 or polycarbonate. The off-diagonal data (15 vs 3) suggest that generally the polycarbonate lenses are preferred to CR-39 ($p < .01$). These data are in good agreement with the results for the 2 previous evaluations.

TABLE 5. RESPONSE TO QUESTION 7 FOR EACH CR-39 AND POLYCARBONATE PAIR ON 81 SUBJECTS

(12-month evaluation)

		CR-39 lens		
		Yes	No	Total
Polycarbonate lens	Yes	59	15	74 (91.4%)
	No	3	4	7
	Total	62 (76.5%)	19	81

NOTE:

Eleven subjects did not respond to question 7; 5 subjects responded only to part of the questions.

11 + 5 + above 81 = total of 97 evaluated at 12 months

Summary of responses to questions 1 and 2 at the 12-month evaluation is given in Table 6. Generally, the results show that at least 90% of the participants wore these spectacles most of the time and that they were comfortable. The responses to questions 4, 5 and 6 were not reported since the data were not available by lens type.

TABLE 6. SUMMARY OF RESPONSES TO QUESTIONS 1 AND 2

(12-month evaluation)

No.	Question	Response (%)*	
1	Did you wear the glasses all the time?		
	Yes	58/95	(61.1%)
	Most of the time	30/95	(31.6%)
	Hardly at all	7/95	(7.4%)
2	Were the glasses comfortable?	90/95	(94.7%)

* The percentages are based on the total number of subjects who responded to the question, not the total number of subjects evaluated (97).

CONCLUSIONS

The data from this field-use study showed that hard-coated polycarbonate lenses were more abrasion-resistant than uncoated CR-39 lenses after about 1 year of field use. Data were consistent from both the optician's and participants' responses on both the 4- and 12-month evaluations.

RECOMMENDATIONS

A coated polycarbonate prescription lens with acceptable field life is now available to provide superior eye protection. To recommend this lens as a substitute for glass or CR-39 materials is premature. Field tests using live weapons for real-world ballistic performance are needed. Material thickness effects should be investigated. The cost of lens fabrication, including laboratory tooling costs, must also be considered.

We do recommend that hard-coated polycarbonate lenses be issued to combat personnel potentially exposed to antipersonnel weapons. Rescue crews, low-level flight crews, armored infantry, and tank crews would certainly benefit from this protection.

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