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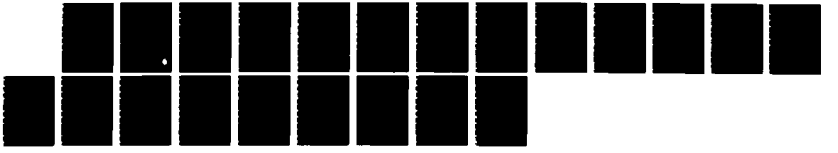

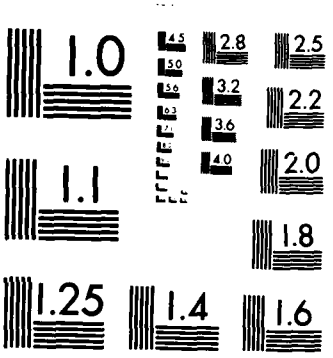

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ABRASION-RESISTANT COATED VERSUS NONCOATED CR-39 OPHTHALMIC LENSES: A FIELD STUDY

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Approved for public release; distribution is unlimited.

USAF SCHOOL OF AEROSPACE MEDICINE
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NOTICES

This final report was submitted by personnel of the Ophthalmology Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7755-24-06.

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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 nations.

This report has been reviewed and is approved for publication.

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The surface abrasion characteristics of 150 pair of ophthalmic spectacle lenses were evaluated quarterly for 1 yr of wear at Nellis Air Force Base, Nevada. The spectacle lenses were plastic CR-39, but one lens in each pair was coated with a special abrasion-resistant coating. This coating is a newly developed process that is relatively easy to work with and can be applied by local optical laboratories. However, the abrasion-resistant coated lenses were not found to be significantly different from the uncoated lenses at the 8- and 12-month evaluations.

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ABRASION-RESISTANT COATED VERSUS NONCOATED CR-39 OPHTHALMIC LENSES: A FIELD STUDY

INTRODUCTION

Plastic CR-39 ophthalmic lenses exhibit significantly more impact resistance than regular crown-glass tempered lenses (1, 2). Plastic lenses are also one-half the weight of glass and possess a lower coefficient of thermal conduction, i.e., fog up less. Lexan (polycarbonate) ophthalmic lenses possess even more desirable impact-resistance properties than CR-39 lenses (3); however, they possess some disadvantages, such as being difficult to optically fabricate and being more costly. The advantages of plastic lenses continue to warrant evaluation as the lens of choice for military use. Before the armed services convert from glass to plastic lenses, however, their durability and surface hardness must be demonstrated. Rengstorff (4) reported that 97% of the spectacles containing plastic lenses were still usable at the end of 9 weeks of advanced infantry training, as compared to only 84% of the spectacles containing glass lenses. On the other hand, most long-term studies (5, 6, 7) have reported that CR-39 lenses scratched excessively, had a significantly higher replacement rate, and were less durable than glass. However, the use of a scratch-resistant coating for CR-39 lenses has been reported to greatly increase the durability of lenses (8, 9). Uncoated CR-39 lenses have a life span of about 1 yr in the USAF field environment (10). The coating of CR-39 lenses may markedly extend this life, thereby significantly reducing replacement costs. A field study that directly compared coated CR-39 lenses vs. noncoated CR-39 lenses would provide realistic data upon which to base future recommendations. Therefore, the primary purpose of this study was to determine if a coating would significantly increase the field-use life of CR-39 ophthalmic lenses. Recently, a process was developed which allows abrasion-resistant coating of CR-39 lenses by local optical laboratories. The Research Optical Unit at USAFSAM acquired the equipment and expertise to apply the coating to lenses. A research protocol was devised to determine how feasible this procedure would be for military use and, most importantly, how good this coating is under actual field conditions.

METHOD

At Nellis AFB, Nevada, 150 USAF personnel were issued prescription spectacles with CR-39 plastic ophthalmic lenses. One lens in each pair was coated with a new abrasion-resistant coating. The coating was applied at the USAF School of Aerospace Medicine (USAFSAM), Ophthalmology Branch, Physical-Physiologic Optics Function, Optical Research Laboratory, Brooks AFB, Texas.

The laboratory procedure for coating the lenses was as follows:

1. The lenses were first soaked in Action protective coating #1811 for 20 min.

2. The lenses were blown dry to remove any bubbles.

3. The lenses were then heated for 10 min at 200 °F (94 °C).

4. After being cleaned with water and inspected for impurities, the lenses were inserted into the frames. The coated lens was always placed in the right side of the frame. The information was known only to the optician who fabricated the finished eyeglasses.

Nellis AFB was chosen as the test base. The dusty and windy environment had, on previous occasions, provided a severe environmental field test for lens durability performance (8). Optometry Clinic personnel at the USAF Hospital Nellis supported this study by providing routine eye examinations and through the use of their facilities. Four months prior to initiating the test, subjects were selected and spectacles ordered. The criteria for subject selection were that they must be nonaircrew active duty, work outdoors some of the time, wear their spectacles most of the time, and have at least 1 yr remaining on station. Upon dispensing the 150 pairs of prescription lenses in the aircrew frame, each subject was instructed as follows:

1. The spectacles are nonstandard, but should be treated as ordinary eyeglasses.

2. The lenses will be replaced should breakage or severe deterioration occur, but ordinary tempered glass lenses will be used and the participant will be dropped from the study.

3. At 4, 8, and 12 months after the initial dispensing of the spectacles, an on-site evaluation will be made. Each subject must bring in his spectacles for evaluation at that time and complete a short questionnaire.

4. At the end of the study (12 months), the spectacles will be returned to the experimenters. If the subject has fulfilled his obligations, then the aircrew frame will be returned to him with a new set of tempered glass lenses inserted in place of the test lenses.

The on-site evaluations were made at 4-month intervals by a research optometrist and technician of the Physical-Physiological Optics Function of the USAFSAM Ophthalmology Branch. At each evaluation, the examiner visually inspected the lenses and recorded a durability score for each of 3 zones on each lens pair. The 3 zones were the central 10-mm zone, between 10-mm and 20-mm concentric circles, and beyond the 20-mm concentric circle. The following criteria were used to rate the durability of each zone of each lens:

0 = no observed scratching
1 = a few superficial scratches
2 or 3 = successive severity of number and penetration of scratches

An example of the form used to rate the lenses is in Appendix A. To ensure objectivity, previous score records were not made available during the 8- and 12-month on-site evaluations, and the examiner was unaware of which lens was coated. While the lenses were being inspected, the subject filled out a questionnaire (Appendix B).

Postcards were mailed a week prior to lens evaluation dates, notifying the subjects to bring their glasses to the Nellis Optometry Clinic. A notice

of evaluation dates was also placed in the Nellis Base Bulletin. The response rates are shown in Table 1. These response rates were 63% (95/150) for the 4-month evaluation, 55% (78/142) for the 8-month evaluation, and 48% (66/137) for the 12-month evaluation. The relatively high attrition rate resulted from the excessive amount of TDY among personnel at Nellis AFB.

TABLE 1. SUMMARY OF THE INFORMATION ON THE NUMBER OF PARTICIPANTS AT EACH OF THE THREE EVALUATION PERIODS

Evaluation	Remarks
4-month (150 participants)	Questionnaire response - 95[a]
	Scored - 92[b]
	Not evaluated - 55
8-month (142 participants)	Questionnaire response - 78[c]
	Scored - 73[d]
	Not evaluated - 64
12-month (137 participants)	Questionnaire response - 66
	Scored - 66
	Not evaluated - 71

[a] 5 were eliminated from the study
[b] 2 lost their glasses and 1 had a lens missing
[c] 3 were eliminated from the study
[d] 1 lost glasses, 1 phone interview, 1 ?,
2 arrived too late for scoring

RESULTS AND DISCUSSION

Two types of durability scores were analyzed as follows:

1. ScoreMax = the maximum reading among the three zones

2. ScoreI = the reading for zone I only

The ScoreMax reflects the worse score for the lens, regardless of zone, and the ScoreI reflects the scratching in the most critical zone.

Table 2 summarizes the abrasion ScoreMax values for each pair of lenses at the 4-, 8-, and 12-month evaluations. For example, at the 4-month evaluation, 14 pairs of lenses showed a ScoreMax value of 1 for the uncoated lens and a ScoreMax of 0 for the coated lens. For this evaluation, the optician recorded the same ScoreMax value for both lenses on 55 pairs (diagonal data: 28+15+6+6). The diagonal responses do not aid in deciding whether the coated or noncoated lenses are better. On 25 of the remaining 37 pairs, the score was worse for the noncoated lenses than for the coated lenses ($P<.05$) (Wilcoxon test). The figure of 25 comes from (14+7+1+3), above diagonal total.

TABLE 2. SCOREMAX FOR EACH CR-39 COATED AND NONCOATED LENS PAIR AT EACH EVALUATION

4-month evaluation - 95 participants

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	28	14	0	0
	1	8	15	7	1
	2	3	0	6	3
	3	0	0	1	6

8-month evaluation - 78 participants

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	14	7	0	0
	1	5	14	9	0
	2	0	5	7	1
	3	0	0	5	6

12-month evaluation - 66 participants

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	15	2	0	0
	1	2	10	5	0
	2	0	3	18	4
	3	0	0	1	6

For the 8-month evaluation, 17 out of 32 off-diagonal pairs showed the ScoreMax value to be worse for the noncoated lenses than for the coated lenses ($P>.05$). For the 12-month evaluation, 11 out of 17 off-diagonal pairs showed the ScoreMax value to be worse for the noncoated lenses than for the coated lenses ($P>.05$). Although a trend existed in the ScoreMax variable, at only

the 4-month evaluation did the coated lenses show a statistically significant difference in scratching than the noncoated lenses. Table 3 summarizes the abrasion ScoreI values for each pair of lenses at the 4-, 8-, and 12-month evaluations.

TABLE 3. SCOREI FOR EACH CR-39 COATED AND NONCOATED LENS PAIR AT EACH EVALUATION

4-month evaluation - 95 participants

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	51	10	0	0
	1	9	10	2	1
	2	2	2	1	0
	3	0	1	0	3

8-month evaluation - 78 participants

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	31	6	3	0
	1	6	14	3	0
	2	1	2	2	0
	3	0	0	2	3

12-month evaluation - 66 participants

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	19	2	0	0
	1	3	5	6	0
	2	0	3	17	4
	3	0	0	2	5

Of the 27 off-diagonal pairs in the 4-month evaluation, the ScoreI values were worse for the noncoated lens on 13 lenses (P>.05). At the 8- and 12-month evaluations, 12 pairs had a worse score for the noncoated than the coated lens for each month out of 23 and 20 off-diagonal values, respectively. The hypothesis of no difference between the coated and noncoated lenses could not be rejected (P>.05) at any evaluation. Thus, no statistically significant difference was found.

To measure the accuracy of the examiner's scoring, one would need independent repeated scorings on the same lens under identical conditions. Since the data were not available, we decided to check on the scoring consistency by comparing abrasion scores between the 12-month and the 4-month ScoreI evaluations. You would expect the lenses to get worse over time (smaller scores) or, at best, stay the same. Any "improvement" over time (smaller scores) can be an error in scoring. The comparison of the abrasion scores between the 4- and 12-month evaluations for the coated and noncoated lenses separately is given in Table 4.

TABLE 4. CONSISTENCY CHECK ON EXAMINER'S SCORES (SCOREI)
(4-month vs. 12-month)

Noncoated (left) lenses

4-month evaluation	12-month evaluation 0	1	2	3	
0	21	14	0	1	
1	3	7	6	2	
2	1	0	2	0	
3	0	0	1	1	Total: 59

Coated (right) lenses

4-month evaluation	12-month evaluation 0	1	2	3	
0	23	9	1	2	
1	4	7	5	1	
2	0	3	2	0	
3	0	0	1	1	Total: 59

Identical scores were reported for 31 noncoated and 33 coated lenses. Only 5 out of 59 noncoated lenses showed improvement, i.e., less scratching at 12 months than at 4 months, while only 8 out of 59 coated lenses showed improvement. These results indicate that the examiner's scoring criteria were consistent.

The lenses with the worst abrasion, as reported in Question 3 of the participants' subjective questionnaire (Appendix B), were compared for the 12-month data only in Table 5. The noncoated lens was chosen 11 out of 20 times (55%) by the participants as the worse lens ($P>.05$). This finding is consistent with the results of the examiner's evaluations.

TABLE 5. QUESTION 3: LENS WITH THE WORSE SCRATCHING... (12-month evaluation)

Worse Lens:	
Right (coated)	9
Left (noncoated)	11
Others:	
No scratching	33
Both scratched (but no "worse" lens)	12
Scratched but no location given	1

The responses to Question 7 were analyzed in the same manner as the durability scores. The results are shown in Table 6. The diagonal data (57+1) do not aid in deciding the preference for coated lens over noncoated lens. The off-diagonal data (1 vs. 1) suggest that generally the participants had no preference between the coated and noncoated lenses.

Table 7 summarizes responses to Questions 1 and 2 at the 12-month evaluation. Generally, the results show that 64% of the participants wore their spectacles all or most of the time and that the spectacles were comfortable. We found it a little disturbing that only 64% of the participants wore their spectacles all or most of the time. Maybe it was the other 36% that had a considerable influence on our previously reported results. To better understand the consistency of the responses to Question 1, we decided to compare these responses among the three evaluations. On 56 participants' questionnaires, the responses were consistently "all the time" or "most of the time" among the times for which they were evaluated, while for another 26 participants, the responses were consistently "hardly at all" or "other."*

*"No" to "all the time," but no response to "most of the time" or "hardly at all."

TABLE 6. RESPONSE TO QUESTION 7 FOR EACH COATED AND NONCOATED LENS PAIR FOR THE 12-MONTH EVALUATION

Question 7: Do you think that the lenses used in the test should be considered for standard military spectacles?

Noncoated lens*	Coated Lens* Yes	Coated Lens* No
Yes	57	1
No	1	1

*6 participants did not respond

TABLE 7. SUMMARY OF RESPONSES TO QUESTIONS 1 AND 2 (12-month evaluation only)

Question 1: Did you wear the glasses all the time?

Responses	
Yes	15/66 (23%)
Most of the time	27/66 (41%)
Hardly at all	13/66 (20%)
Other	11/66 (17%)

Question 2: Were the glasses comfortable?

Responses	
Yes	61/66 (92%)
No	5/66 (8%)

The responses were inconsistent on another 20 participants, switching from "hardly at all" to "all the time" on occasion. Only in a few cases can one relate the decrease in frequency of wearing the spectacles with perhaps scratchings on the lenses. Perhaps we can "tighten up" this question in future studies so that all participants can give more consistent responses.

Because of this concern over the consistency of the response to Question 1 on certain individuals, we decided to reevaluate the ScoreMax and ScoreI ratings in Tables 2 and 3 by using only the data from the participants who consistently reported wearing their spectacles all or most of the time. The results are shown in Tables 8 and 9. As previously mentioned, we will concentrate only on the off-diagonal counts. On 13 out of 21 off-diagonal ScoreMax pairs, the noncoated abrasion rating was higher than the coated rating at the 4-month evaluation. For the 8- and 12-month evaluations, the comparable proportions were 9 out of 18 and 5 out of 9, respectively (Table 8). For the ScoreI ratings in Table 9, the same proportions for the 4-, 8-, and 12-month evaluations were 5 out of 12, 5 out of 12, and 3 out of 5, respectively. None of the proportions differed significantly from the null hypothesis of half of the pairs showing coated ratings greater than the noncoated ratings and the other half showing the reverse.

Table 10 summarizes the responses to Questions 4, 5, and 6 for the 12-month evaluation only. Although the data are of general interest, they are not lens (coated vs. noncoated) specific and hence cannot be used as covariates.

CONCLUSION/RECOMMENDATION

Although a consistent trend is evident, the data of this study failed to show that the coated CR-39 lenses are significantly more abrasion-resistant than the noncoated CR-39 lenses after 1 yr of field use. In only one instance was there a significant difference found in favor of the coated lens, and that was for the ScoreMax values at the 4-month evaluation. This significant difference disappeared at the 8- and 12-month evaluations. In addition, data was shown to be consistent for the experimenters' criteria and the participants' responses on the three evaluations. Therefore, although this new type of coating is relatively easy to apply, we cannot advocate it for USAF field use.

TABLE 8. SCOREMAX FOR EACH CR-39 COATED AND NONCOATED LENS PAIR AT EACH EVALUATION FOR PARTICIPANTS WHO WORE THEIR SPECTACLES ALL OR MOST OF THE TIME

4-month evaluation

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	16	9	0	0
	1	6	7	2	0
	2	1	0	1	2
	3	0	0	1	5

8-month evaluation

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	6	3	0	0
	1	3	7	5	0
	2	0	4	4	1
	3	0	0	2	3

12-month evaluation

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	10	0	0	0
	1	1	2	2	0
	2	0	2	9	3
	3	0	0	1	4

TABLE 9. SCOREI FOR EACH CR-39 COATED AND NONCOATED LENS PAIR AT EACH EVALUATION FOR PARTICIPANTS WHO WORE THEIR SPECTACLES ALL OR MOST OF THE TIME

4-month evaluation

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	29	5	0	0
	1	3	6	0	0
	2	2	1	0	0
	3	0	1	0	3

8-month evaluation

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	16	1	1	0
	1	3	7	3	0
	2	1	2	2	0
	3	0	0	1	1

12-month evaluation

		Noncoated Lenses			
		0	1	2	3
Coated Lenses	0	13	1	0	0
	1	1	8	2	0
	2	0	1	5	0
	3	0	0	0	3

TABLE 10. SUMMARY OF RESPONSES TO QUESTIONS 4, 5, AND 6 (12-month evaluation only)

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

Responses

Great deal	2/32 (6%)
Some	14/32 (44%)
Not at all	16/32 (50%)

Question 5: Were there any unusual experiences noticed with spectacle wear?

Yes responses	15/66 (23%)

Question 6: How do you usually clean your lenses? (Some participants gave several responses.)

Responses

	Wet	Dry	Both
Handkerchief	5	12	2
Kleenex	10	29	1
Paper towel	10	7	2
Other	3	3	1

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APPENDIX A

PLASTIC LENS DATA CARD

NAME									SSAN						
SAMPLE									327-65-4731						
DATE			RIGHT				LEFT					REMARKS			
DAY	MO	YR	M	I	II	III	M	I	II	III		A	B	C	
			4 Mos Bupl	1	2	1		2	1	2					

AMD FORM APR 64 598 PLASTIC LENS DATA CARD

APPENDIX B

OPTICAL QUESTIONNAIRE

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_____

   _____

   _____

(Continued on reverse)

6. How do you usually clean your lenses?

HANDKERCHIEF_____ WET_____ DRY_____

KLEENEX_____ WET_____ DRY_____

PAPER TOWEL_____ WET_____ DRY_____

OTHER (Please explain)_____

_____

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:_____

_____

_____

END

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