The Effect of Coatings on Impact Resistance

In 1971 the Food and Drug Administration issued their regulation that required all lenses dispensed in the US to be impact resistant. Impact resistance was defined as the ability of the lens to withstand the impact of a 5/8" steel ball dropped 50" on the lens supported by a particular mount.

In 1971 about half the lenses dispensed in the US were glass and half were allyl diglycol carbonate (ADC), more commonly known as CR-39®. At that time, manufacturers of ADC warranted that their plastic lenses would pass the Drop Ball Test. Because of the warrant, laboratories did not have to impact test plastic lenses.

The introduction of new lens materials and the growth of abrasion resistant coatings and thin film coatings such as anti-reflection coatings changed that. In 1991 and again in 1998 the OMA (predecessor to the OIA and VCA) stated "New materials such as polycarbonate, hard-resin-like high-index plastics, and new types of glass have also entered the market. Many of these materials require modified surfacing processes and back surface coatings and, as a result, have their back surface altered by the processor during coating. The materials also have different relative impact strengths and are affected differently by processing, scratch resistant and/or anti-reflective coating. Therefore, the original manufacturer cannot warrant the final lens' impact resistance via factory impact testing. In this case, the secondary processor becomes the manufacturer and must assume the manufacturer's responsibilities".

Coatings are one of the primary variables in impact resistance. An understanding of the extent to which coatings alter impact resistance can be gained by reviewing some of the research done in this area.

In 1991 at the OLA Annual Meeting, Nippon Sheet Glass presented a seminar that showed the impact strength as measured with the Drop Ball Test of uncoated, scratch coated (front and back surfaces) and scratch coated + AR coated ADC and 1.601 lenses.

Drop Ball Test Fracture Height (inches)

Mfg	Index	Thickness (mm)	Uncoated	Scratch Coated	Scratch + AR Coated
A	1.498	1.5	927	105	25
B	1.498	1.9	397	160	32
C	1.498	2.0	630	182	32
D	1.498	2.5	830	212	72
E	1.498	2.6	1005	325	120
F	1.601	2.1	>1165	220	158
G	1.601	2.6	317	302	75
H	1.601	1.9	125	242	17

These results show the impact strength of scratch coated lenses drop by up to 87% and the impact strength of scratch coated + AR coated lenses drop by up to 97%. In some cases, surface treatments such as hardcoating and/or AR coating have more effect on the impact resistance of a lens than does the lens material itself. It is also apparent that in some cases the addition of a scratch coating plus an AR coating decreases the impact resistance below the FDA requirement.

A 1996 article in Optometry & Vision Science entitled "Effects of Coatings on the Fracture Resistance of Ophthalmic Lenses" cited test results on the effects of scratch coatings and AR coatings on the fracture resistance of lenses using a static load test. After converting their test results to equivalent fracture height (i.e. the height at which a lens would break in the drop ball test), the data showed the following.

Static Load Test Equivalent Fracture Height (inches)

Sample	Center Thickness (mm)	Mean Fracture Height
Uncoated ADC	2.41	277
Scratch Coated	2.48	117
AR Coated	2.41	102

These results clearly show a dramatic decrease in impact resistance when coatings are applied.

Unpublished test results by Torgersen similarly show a decrease in impact strength for glass, ADC, and mid-index 1.56 Plastic.

Drop Ball Test Fracture Height (inches)

Sample	Center Thickness (mm)	Fracture Height
Uncoated 1.56	2.1	251
AR Coated 1.56	2.0	84
Uncoated ADC	1.7	378
AR Coated ADC	1.8	150
Uncoated Glass	2.2	504
AR Coated Glass	2.2	250

It is apparent that AR coatings decrease impact strength. It is also clearly apparent that different lens materials will be affected differently.

Adding to the complexity, different lab-applied back surface hardcoatings affect impact resistance differently. Unpublished data by Torgersen assessed the impact resistance using the Drop Ball Test on different types of backside coatings with the following results.

Fracture Height (inches) for Backside Coatings

Sample	CT (mm)	Fracture Height
Thermal Coated	2.16	365
UV Coated	2.20	577
Uncoated	1.99	502

When adjusted for center thickness, there was no statistically significant difference in impact strength of uncoated and UV coated lenses. However, there was a statistically significant difference between uncoated or UV coated lenses and thermal coated lenses.

Who does impact resistance testing?

The FDA defines the manufacturer as ". . . the person who puts the lens in the form ready for its intended use or who alters the physical or chemical characteristics of the lens by such acts as grinding, heat treating, beveling, or cutting". In the case of surfaced lenses, the laboratory is the manufacturer and must conduct impact testing. If lenses are sent out to be coated, the coater is altering the chemical characteristics of the lens and therefore becomes responsible for conducting impact testing. Laboratories sending lenses out for coating should make certain the coater is aware that they are responsible for testing. If the coater does not test impact resistance, the laboratory is then responsible for assuring impact resistance.

Summary

We can conclude the following:

1. Manufacturers do not warrant impact resistance of surfaced lenses or of finished AR or backside coated lenses when the manufacturer has not applied the coating. It is the responsibility of the lab or the coating service to conduct impact resistance testing.

2. Impact resistance can be significantly affected by lab-applied back surface hardcoatings. Each lab should request information from the manufacturer of the lenses they use on the impact performance using different back surface lab-applied hardcoatings. Similarly, labs should request information from the manufacturer of the back surface hardcoating supplier on the impact performance of lenses coated with that specific hardcoat.

3. AR coatings significantly affect impact resistance. Each lab should request information from the manufacturer of the lenses they use on the impact performance using AR coatings and AR coating in combination with back surface lab-applied hardcoatings. Similarly, labs should request information from the manufacturer of the AR coating supplier on the impact performance of lenses coated with that specific AR coating.

4. Labs should confirm that the AR coating service they use is aware that impact resistance testing is their responsibility.

5. Labs should conduct impact testing on the combinations of lens materials, hardcoatings and AR coatings.