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# Equilibrium water content and glistenings in acrylic intraocular lenses

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**Purpose:** To investigate the possible relationship between temperature and water absorption in acrylic intraocular lenses (IOLs).

**Setting:** Laboratory setting, Miyata Eye Clinic, Hiroshima, Japan.

**Methods:** The equilibrium water content (amount of water absorbed per weight of the resin  $\times$  100) in 2 hydrophobic acrylic IOLs (AcrySof<sup>®</sup> MA60BM [Alcon] and Sensar<sup>®</sup> AR40 [AMO]) was calculated at 30°C, 40°C, and 50°C. The 2 IOLs were also subjected to 3 changes in temperature: from 37°C to 35°C, 39°C to 35°C, and 41°C to 35°C. They were incubated in physiological saline at the higher temperature for 2 hours and at the lower temperature for 30 days before being examined for glistening formation.

**Results:** The water content was higher in the AR40 IOL than in the MA60BM IOL at all temperatures. A temperature-dependent increase in water content was seen in both IOLs, greater in the MA60BM. With a temperature change from 37°C to 35°C, glistening formation was not observed in either IOL. With a temperature change from 39°C to 35°C, glistenings were observed in the MA60BM IOL, and with a temperature change from 41°C to 35°C, they were observed in both IOLs.

**Conclusion:** The change in the equilibrium water content caused by temperature changes between 30°C and 40°C is an important factor in glistening formation, and thus an IOL featuring less temperature-dependent water absorption is less likely to form glistenings.

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With the increased frequency of small-incision cataract surgery, the use of foldable soft intraocular lenses (IOLs) is expanding. Among foldable soft IOLs, acrylic IOLs are popular because there is a low incidence of postoperative inflammation and posterior capsule opacification with them.<sup>1</sup> However, glistening formation has been observed in certain acrylic IOLs,<sup>2</sup> and there is some concern about the effect of glistenings on visual function. Currently, it is assumed the glistenings

are caused by the formation of water bubbles in the material and not by deterioration of the material.<sup>3,4</sup> It has been reported that the glistenings do not worsen beyond a certain point<sup>5</sup> or have a significant effect on visual function.<sup>3,6</sup>

Glistening formation has also been observed in certain silicone IOLs,<sup>7,8</sup> suggesting that it may be a problem with soft IOLs in general and is not limited to acrylic materials.

Even if it has little effect on visual function, glistening formation should not occur. Thus, it is necessary to elucidate the mechanism of glistening formation so new materials in which glistenings do not occur can be developed. Reports demonstrate that temperature change is involved in glistening formation.<sup>3,5,9,10</sup> Based on this, we hypothesized that a change in the water content of the IOL at different temperatures leads to glistening formation. In this study, we measured the

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**Table 1.** Equilibrium water content of 2 hydrophobic acrylic IOLs.

Acrylic IOL	30°C	40°C	50°C
AcrySof MA60BM	0.12% ± 0.02%	0.20% ± 0.03%	0.43% ± 0.06%
Sensar AR40	0.66% ± 0.06%	0.69% ± 0.09%	0.81% ± 0.07%

Mean ± SD

equilibrium water content of 2 hydrophobic acrylic IOLs at different temperatures to determine the possible relationship between temperature and water content. To relate this to glistening formation, we also experimentally determined the temperature change (decrease) required for glistening formation.

## Materials and Methods

### Equilibrium Water Content

The equilibrium water content was measured in 10 AcrySof® MA60BM IOLs (+20.0 diopters [D]; Alcon) and 10 Sensar® AR40 IOLs (+20.0 D; AMO) at 30°C, 40°C, and 50°C according to the following procedure.

1. The initial weight (*A*) of each IOL was measured using a Mettler M3 microbalance scale (Mettler-Toledo International, Inc.).
2. The IOL was immersed in distilled water and immediately removed. It was lightly pressed 3 times with Kimwipes® Wipers S-200 (Kimberly-Clark Corp.) and covered with cotton paper (Bemcot lint-free PS-2, Asahi Chemical Industry Co., Ltd.) to remove the excess water. The weight (*B*) was measured, and the water adhering to the surface (*C*) was calculated.
3. The IOL was immersed in distilled water for 24 hours at a fixed temperature of 30°C, 40°C, or 50°C. The container for the 30°C water bath was an Eyelatron FLI-160 incubator. A BK-43 constant-temperature water bath was used for the experiments at 40°C and 50°C.
4. The IOL was taken out of the water; excess water was removed, as in step 2; and the weight (*D*) was measured.
5. The equilibrium water content was calculated by the following equation:

Water adhering to the surface after first immersion (*C*)

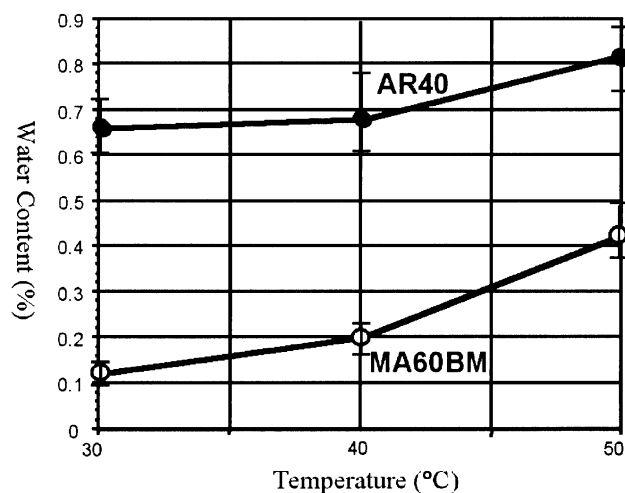
$$= (B - A)$$

Equilibrium water content (%)

$$= (D - C - A)/A \times 100$$

### Glistening Formation

Three AcrySof MA60BM +20.0 D IOLs and 3 Sensar® AR40 +20.0 D IOLs were used. The IOL to be examined



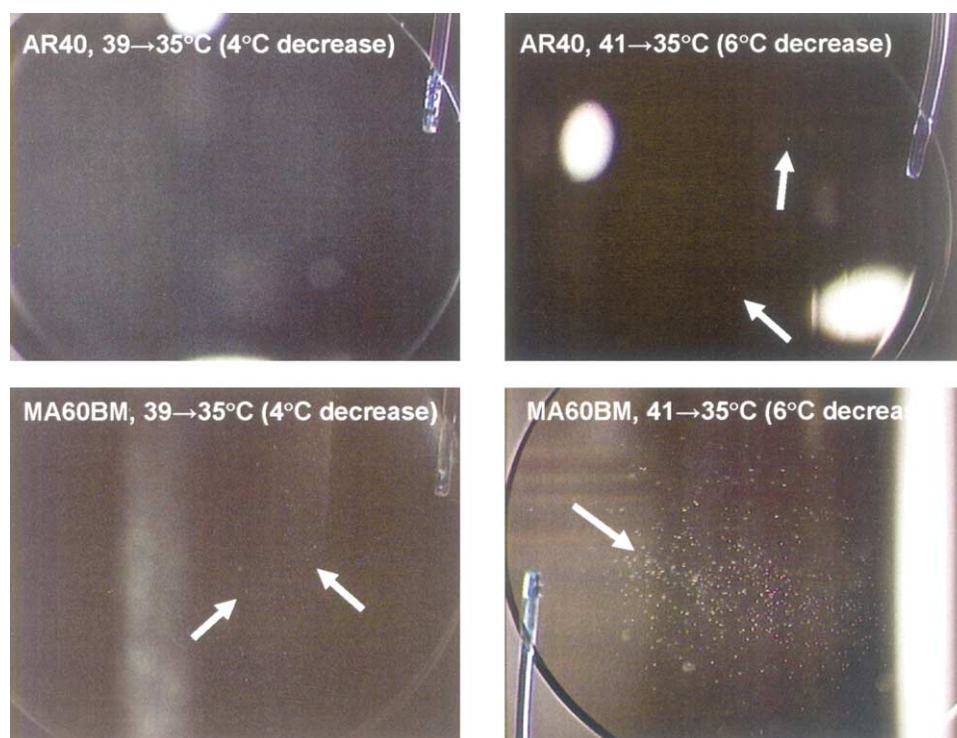
**Figure 1.** (Miyata) Equilibrium water content in the 2 acrylic IOLs (values from Table 1). The AR40 IOL has a higher water content but shows a smaller increase in equilibrium water content with increasing temperature.

was fixed on a thin plastic plate (observation table). A hole was made in the center of the observation table so the optic did not come in contact with the table, and the IOL was affixed to a loop. The observation table was lifted and immersed in 50 cc of physiological saline held in a transparent screw-top bottle at a high temperature (37°C, 39°C, or 41°C). The bottle was then placed in an incubator (UI-59, Iuchi Seieido Co., Ltd.) and maintained at a stable temperature. After immersion for 2 hours, the IOL and observation table were moved to a transparent screw-top bottle containing 50 cc of physiological saline at 35°C and placed in an incubator maintained at 35°C. On day 30 of immersion, the IOL was observed with a slitlamp microscope through the screw-top bottle. A piece of black paper was attached to the rear surface of the bottle to allow careful observation of the IOL for evaluation of glistening formation.<sup>3,5</sup>

## Results

### Equilibrium Water Content

Measurement of the equilibrium water content of the MA60BM and AR40 IOLs at 30°C, 40°C, and 50°C (Table 1 and Figure 1) showed that the water



**Figure 2.** (Miyata) Glistening formation in the 2 acrylic IOLs. With a temperature decrease from 39°C to 35°C, glistening (white arrow) was observed in the MA60BM IOLs (lower left) but not in the AR40 IOLs (upper left). With a temperature decrease from 41°C to 35°C, glistening was observed (white arrows) in the AR40 IOLs (upper right) and in the MA60BM IOLs (lower right).

content increased as the temperature increased. The water content was higher in the AR40 IOLs at all temperatures, but the temperature-dependent increase in water content with increasing temperature was less in the AR40 IOLs than in the MA60BM IOLs.

#### *Glistening Formation*

When the IOLs were subjected to a temperature change from 37°C to 35°C (decrease of 2°C), glistening formation was not observed in either type. When the temperature was reduced from 39°C to 35°C (decrease of 4°C), a small amount of glistening was observed in the MA60BM IOL but no glistening was observed in the AR40 IOL. When the temperature was reduced from 41°C to 35°C (decrease of 6°C), a small amount of glistening was observed in the AR40 IOLs and a larger amount was observed in the MA60BM IOLs (Figure 2).

## Discussion

Acrylic resin, which is thermoplastic, is produced by polymerizing a monomer (material), an initiator,

and a crosslinking agent. If there is a nonhomogenous gap in the polymer, water is likely to collect at the gap. This gap is called a void and is thought to cause glistening formation.<sup>3,5,7</sup> The void is normally impossible to observe; it becomes noticeable only when water collects and causes glistening. If a material were polymerized with ideal homogeneity, voids or glistenings would not form in the material; however, some void formation is inevitable in any polymerization process. Manufacturers have methods of varying monomer materials and polymerization conditions to reduce voids. Of the 2 IOL manufacturing methods—lathe-cutting and molding—it is thought that lathe cutting, in which resin is polymerized in the form of a sheet, is more likely to allow homogenous polymerization, resulting in fewer voids.<sup>11</sup>

When an IOL is immersed in water, a small amount of water infiltrates the IOL material. The amount of infiltration differs depending on the material; it is about 0.5% for hydrophobic acrylic resin and less than 0.1% for silicone.<sup>12</sup> Near the glass-transition temperature, the equilibrium water content changes with the temperature: the higher the temperature, the higher the equi-

librium water content.<sup>4,12</sup> Therefore, as intraocular temperature changes, the equilibrium water content of the IOL material changes. In particular, when the temperature decreases from high to low, excess water is produced in the material. The water separates into phases and collects in a void, generating glistenings.<sup>5</sup>

In the present study, we measured the equilibrium water content of 2 hydrophobic acrylic IOLs and found that the water content differed between them and increased with temperature. The equilibrium water content was higher in the AR40 IOL than in the MA60BM IOL at all temperatures. The change in equilibrium water content due to temperature is expressed as the slope of the line shown in Figure 1. The change in equilibrium water content was greater in the MA60BM IOL than in the AR40 IOL. It is thought that in IOLs whose water content varies significantly with temperature, excess supersaturated water is likely to be produced in the material as the IOL temperature decreases, resulting in phase separation of water and thus in glistening. Conversely, it is presumed that IOLs with less temperature-dependent water absorption are less likely to cause phase separation of water due to temperature change, resulting in less glistening.

In the glistening experiment, we observed glistening formation in the MA60BM IOL with a temperature decrease of 4°C (39°C to 35°C). In the AR40 IOL, glistening formation was not observed with this temperature decrease, but a small amount was observed with a temperature decrease of 6°C (41°C to 35°C). This experiment showed the AR40 IOL has less temperature-dependent water absorption, indicating that phase separation of water is less likely to occur. These findings were consistent with the hypothesis based on the results of the measurement of IOL equilibrium water content at different temperatures.

As stated, glistening formation is known to depend on a change in temperature. Such changes are likely to result from temperature change during lens transportation, temperature change during surgery, and postoperative fluctuations in the intraocular temperature. Since IOLs are packaged in a dry state, temperature change during transportation does not seem to be a probable cause of glistening formation. Fluctuations in the intraocular temperature caused by changes in temperature in the operating room or intraocular infusion solution seem to occur only during or immediately after surgery.

Therefore, we believe that postoperative fluctuations are the most likely cause of glistening formation.

We know of no reports investigating the extent of intraocular temperature fluctuations postoperatively. Body temperature is about 36°C, and the intraocular temperature is therefore considered to be about 36°C. However, the intraocular temperature is probably affected by systemic pyrexia due to colds and pneumonia, so the intraocular temperature is presumed to actually fluctuate between 30°C and 40°C. If a material featuring a smaller change in the equilibrium water content within this temperature range were produced, the material would be free of glistening formation.

The study data suggest that the change in the equilibrium water content of IOLs at temperatures between 30°C and 40°C is an important factor in glistening formation. Of currently available IOL materials, those featuring less temperature-dependent water absorption are less likely to incur glistenings.

Finally, we would like to emphasize that the present study was intended to reveal the possible relationship between glistening formation and a change in the equilibrium water content in hydrophobic acrylic IOLs. We used only 2 hydrophobic acrylic materials for purposes of comparison, and this study was not intended as a full clinical evaluation of commercially available IOLs.

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