Silicone Intraocular Lens Power vs Temperature

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New, flexible intraocular lenses that can be compressed or folded to allow implantation through a smaller incision than conventional polymethylmethacrylate lenses have optical and physical characteristics that can be significantly different than those of polymethylmethacrylate. Silicone has an index of refraction that changes significantly as a function of temperature. As a result, a silicone intraocular lens measured at a typical inspection facility room temperature of 20 C will have a significantly different power than when implanted in an eye with a nominal temperature of 35 C. We devised a method of properly compensating for this power change as a function of temperature for convexoplano and biconvex lenses.

Silicone and Perspex CQ/UV polymethylmethacrylate slabs, 2 mm thick, were produced in a process identical to the production of clinical intraocular lenses. The slabs were tested for refractive index on a refractometer equipped with a water bath hookup for temperature stability. Multiple readings were taken from several samples at 2-degree intervals from 20 C to 36 C. The accuracy of this technique in measuring the index of refraction was ±0.0002. The instruments were calibrated at 20 C using certified standards.

Calculations were then performed to determine the difference in reduced lens power in aqueous humor at nominal eye temperature (35 C) and at room temperature (20 C) for three representative lens powers for both biconvex and convexoplano lenses. The formula used to calculate the lens power was the thick-lens formula.[1]

$$P_{IOL} = (n_{IOL} - n)\left(\frac{1}{r_1} - \frac{1}{r_2} + \frac{t_c(n_{IOL} - n)}{n_{IOL}\, r_1\, r_2}\right),$$

where P_{IOL} = reduced power of intraocular lens in surrounding media (diopters), n_{IOL} = index of refraction of intraocular lens at a given temperature, n = index of refraction of the surrounding media (aqueous humor or air), r_1 = radius of front surface (convex is positive), r_2 = radius of back surface (convex is negative), and t_c = center thickness.

Measurements of the dioptric power of actual silicone lenses at room and eye temperature in air and water were then performed to validate the accuracy of the calculations.

Refractometer testing showed that the index of refraction for silicone was 1.4128 at 20 C and 1.4080 at 35 C. These values and intermediate values tested at 2-C intervals demonstrated an exact linear rate of change for the index of refraction of -3.2×10^{-4}/degrees C. The indices of refraction for the polymethylmethacrylate were 1.4912 at 20 C and 1.4900 at 35 C. Using the same method for measuring, the rate for the polymethylmethacrylate was -8.0×10^{-5}/ degrees C. These rates were verified by Becke Line testing,[2] another method for measuring indices of refraction, and focal length measurements of actual lenses.

The change for biconvex and convexoplano lenses made of polymethylmethacrylate were less than 0.50 diopter in the extreme case (30-diopter lens), and therefore are not clinically significant. For silicone lenses, the change in power as a function of temperature was increasingly significant as the power of the lenses increased (Table). The optical configuration of the lens (biconvex or convexoplano) did not make a significant difference.

Previous experiments have demonstrated that silicone lenses have resolution capabilities in aqueous humor comparable to those of polymethylmethacrylate lenses.[3-5] However, the change in power of an intraocular lens as a function of temperature for silicone has not been reported. Identification and awareness of this temperature vs dioptric power relationship for silicone and other new materials is extremely important to assure that the manufacturer's labeled power accurately reflects the effective power when implanted in the eye.

The temperature of the aqueous humor of the human eye is sufficiently stable so that once a lens is implanted, dioptric power fluctuations are insignificant. Temperature dependence, however, does make it almost impossible for the surgeon to verify accurately the lens power at the time of surgery without a complicated apparatus that must include temperature regulation. Such a system is not practical and would increase the possibility of contamination as well as lengthen the time of the surgical procedure.

Other types of silicone have been used for intraocular lenses that may have different indices of refraction and a different temperature dependence. As lenses are made from newer materials, care must be taken to assure that these lenses are tested for power and resolution in conditions that simulate the physiologic environment of the aqueous humor, including temperature and chemical characteristics.

TABLE
SILICONE INTRAOCULAR LENS POWER* VS TEMPERATURE

POWER AT EYE TEMPERATURE (35 C)	POWER AT ROOM TEMPERATURE (20 C)	
	BICONVEX LENS	CONVEXOPLANO LENS
10	10.65	10.65
20	21.37	21.33
30	32.01	31.99

*All values represent reduced vergence power in diopters in aqueous humor at the temperature indicated.

References

1. American National Standard for Ophthalmics. Intraocular Lenses. Optical and Physical Requirements, ANSI Z80.7-1984. New York, American National Standards Institute, 1984, pp. 6–12.

2. Wahlstrom, E. E.: Optical Crystallography, ed. 4. New York, John Wiley and Sons, 1969, pp. 106–114.

3. Holladay, J. T., Ting, A. C., Koester, C. J., Portney, V., and Willis, T. R.: Intraocular lens resolution in air and water. J. Cataract Refract. Surg. 13:511, 1987.

4. ———: Silicone intraocular lens resolution in air and water. J. Cataract Refract. Surg. 14:657, 1988.

5. Kulnig, W., Menapace, R., Skorpik, C., and Juchem, M.: Optical resolution of silicone and polymethylmethacrylate intraocular lenses. J. Cataract Refract. Surg. 13:635, 1987.