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## Calculation of the optical power of intraocular lenses.

S. N. Fyodorov,* M. A. Galin,** and A. Linksz.**

*A rather simple clinical approach has been used to derive formulas necessary to calculate the power of pupillary intracameral prosthetics and these have been applied in 150 eyes. In 136 eyes, the postoperative measurements were within one diopter of preoperative calculations.*

The replacement of the human, cataractous lens at the time of cataract extraction with a safe and dioptrically correct intraocular prosthetic device has long been a desirable event. However, a variety of immediate and long-term complications associated with certain types of intracameral lenses led to the use of implants only in those institutions where the chemistry, physics, and mechanics of these lenses were well understood.[1-3] Extensive and successful clinical use of intraocular prostheses in such centers continued on the continent and stimulated both basic and clinical investigations in this country.[4-6] The data that has resulted from these studies clearly confirm the published results of European investigators and indicate that intraocular implants are excellent adjuncts in the rehabilitation of certain cataract patients.

**Table I.** Age distribution of cataract patients. Note high incidence of younger patients due to traumatic cataracts

| *Age (years)* | *No. of patients* |
|---|---|
| <20 | 13 |
| 20-29 | 28 |
| 30-39 | 30 |
| 40-49 | 26 |
| 50-59 | 32 |
| >60 | 9 |

From 1969 onward, under the auspices of the Soviet-American Health Exchange, extensive clinical testing has been carried out to analyze and refine the technique of measurement and the mathematics employed in calculating the necessary power of an intraocular prosthetic lens of Soviet manufacture to permit lens extraction and simultaneous insertion of such a pupillary implant.[7] These studies have involved solely the Fyodorov lens, and the present report is an analysis of clinical results in 150 eyes in which such calculations have been carried out.

***Mathematical considerations.*** The calculation is based on measurements of the axial length of the eye, the refracting power of the cornea, and an estimate of anterior chamber depth with the implant in place. The following formula expresses the relationship between these constituents:

$$D_p = \frac{n - aD_c}{(a-k)\left(1-\frac{kD_c}{n}\right)} \qquad (1)$$

in which "a" represents the axial length (in meters); "k" anterior chamber depth with the pupillary implant in place (in meters); "$D_c$" the refracting power of cornea (in diopters); "$D_p$" the refracting power of the intraocular lens (in diopters and assuming a thin lens); and "n" the refractive index of aqueous and vitreous (1.336). This basic formula may appear formidable, but

**Table II.** Axial lengths of 50 eyes determined by x-ray method and 100 eyes determined by ultrasound

| Axial length of eye (mm.) | 20.0-20.9 | 21.0-21.9 | 22.0-22.9 | 23.0-23.9 | 24.0-24.9 | 25.0-25.9 | 26.0-26.9 |
|---|---|---|---|---|---|---|---|
| X-ray method | — | 1 | 15 | 22 | 11 | 1 | — |
| Ultrasonic method | 2 | 8 | 14 | 42 | 28 | 5 | 1 |
| Average axial length (mm.) | 23.8 | 23.5 | | | | | |

**Table III.** Frequency distribution of corneal refracting power

| Refracting power of cornea (diopters) | 40.0-40.9 | 41.0-41.9 | 42.0-42.9 | 43.0-43.9 | 44.0-44.9 | 45.0 |
|---|---|---|---|---|---|---|
| No. of eyes | 15 | 34 | 43 | 29 | 22 | 7 |
| Average refracting power (diopters) | 42.4 | | | | | |

**Table IV.** Anterior chamber depth of implanted eyes determined preoperatively by mathematical means

| Depth of pseudophakic chamber (mm.) | 2.0-2.4 | 2.5-2.9 | 3.0-3.4 | 3.5-3.9 | 4.0-4.4 |
|---|---|---|---|---|---|
| No. of eyes | 5 | 14 | 60 | 68 | 3 |
| Average depth of pseudophakic chamber (mm.) | 3.2 | | | | |

is truly simple, since only 3 quantities need be considered, and they are all clinically measurable.

Essentially, it is necessary to determine the vergence power of a lens at the pupillary space that will bring rays to a focus on the retina. This vergence in medium n is:

$$\frac{n}{a\text{-}k}. \qquad (2)$$

The cornea, however, supplies some of the necessary vergence power, and at the pupillary space in medium n, the cornea with power $D_c$ in air contributes:

$$\frac{D_c}{1 - \frac{k}{n} D_c}. \qquad (3)$$

Consequently, the power that has to be provided at the pupillary space is:

$$\frac{n}{a - k} - \frac{D_c}{1 - \frac{k}{n} D_c}. \qquad (4)$$

Combining these fractions yields the previously indicated formula.

It should be emphasized that in using this formula for $D_p$, it is not necessary to know what the eye's refraction was prior to surgery, just as it is not necessary to know the preoperative refraction in prescribing spectacles for an aphake.

In essence, if the aphakic eye is considered a reduced eye with only one principal plane in the plane of the cornea and the implant is treated as a thin lens system, then the formula indicates that there is only one power—$D_p$—at distant k from a cornea with a vergence power of $D_c$ that leads to a lens combination whose posterior focal plane is on the retina, the end point of distance "a."

***Materials and methods.*** In early studies, the axial length of the eye was determined via a modification of the x-ray method of Rushton. Later, the axial length of the eye was determined with ultrasound using Krautkramer's Echo-Ophthalmograph at a frequency of 6 MHz. The refracting power of the cornea was determined with an ophthalmometer (corneal thickness was disregarded) by averaging the power of the two major meridians. Pseudophakic chamber depth, though measurable with specific instruments, was calculated by assuming it to be equal to the height of a spherical segment, the radius of which is equal to the radius of curvature of the cornea, and

the internal diameter of which is 1 mm. longer than that of the visible external diameter of the cornea. These values were then substituted in the following formula:

$$k = r - \sqrt{r^2 - \frac{d^2}{4}} \qquad (5)$$

in which "k" represents the pseudophakic chamber depth; "r" radius of curvature of cornea; and "d" diameter of the visible external part of cornea (limbus to limbus in the largest diameter) +1 mm. This technique for measuring anterior chamber depth uses easily measurable quantities and, in fact, is the most significant component of this paper.

By means of the described techniques of measurement and methods of calculation, the intraocular lens power was determined for 150 eyes of 138 patients.

***Results.*** Table I lists the age distribution of the patients studied. The lower than average age incidence for cataract extraction reflects the high incidence of traumatic cataract present in this series. Tables II through IV list the frequency distribution of axial length, corneal refracting power, and anterior chamber depth.

The axial lengths of 50 eyes measured with the x-ray method were found to be between 21.0 and 25.5 mm., while the axial lengths of 100 eyes measured with ultrasound varied from 20.2 to 26.8 mm. The average axial length is in agreement with published measurements using the x-ray and ultrasonographic methods.

The refracting power of the cornea varied between 40.0 and 45.0 diopters. Postoperatively, the refracting power of the cornea changed an average of 0.2 diopters.

The calculated pseudophakic chamber depth varied between 2.0 and 4.0 mm. Postoperatively, by optical measurement, the pseudophakic chamber depth was within 0.03 mm. of the calculated preoperative values in 146 eyes. In three eyes, this difference was 0.05 mm., and in one eye, the pseudophakic chamber depth was 0.9 mm. less than phakic chamber depth before surgery due to the formation of anterior synechias.

In 136 eyes, the postoperative refraction was within one diopter of the desired preoperative calculation. In 12 eyes, the difference was between 1.1 and 2.0 diopters. In only 2 cases, was the deviation more than 2 diopters.

***Discussion.*** Standard cataract extraction with spectacle or contact lens replacement is one of the most successful surgical procedures. Consequently, any alteration to a different refractive or surgical method must maintain this success rate. Early intraocular lens replacement techniques resulted in a host of complications and completely soured the ophthalmic community on this subject. This attitude persisted until recent years but, fortunately, is slowly dissipating essentially because of an ever increasing body of excellent clinical results.

The reasons for early failure were legion. A number of highly competent ophthalmic surgeons utilized the available lenses with little or no knowledge of the chemistry of the plastic, the chemistry and mechanics of the supports, toxicity of sterilizing systems, the technique of sterilization, and so forth. When failures ensued, the subject of intracameral prosthetics was criticized extensively. The more intelligent approach, i.e., logical and sequential basic research was, however, continued in a few centers in Europe so that the knowledge necessary to create safe prosthetic devices continued to evolve.

The present study was undertaken to establish a simple, easily performed mathematical basis necessary to produce consistent visual results when carefully controlled clinical studies are undertaken. These studies have also included retinal image size disparities but have chosen to neglect them as their clinical importance did not seem too meaningful.[8, 9] Further, we have considered the implant as a thin lens system to further simplify these calculations.[10] Long-term animal and clinical studies, underway at New York Medical College and other centers, appear to validate the method of use of this pupillary lens system. The formulas used in the present study should assist greatly in quantifying the result to be anticipated as the use of pupillary implants continues and increases.

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## Antiviral drugs and corneal wound healing.

ANTONIO R. GASSET AND DAVID KATZIN.

*Using a previously described well standardized wound strength model, the fate of different antiviral drugs from corneal wound healing was evaluated. While 1.0 per cent trifluorothymidine and 0.1 per cent cytosine arabinoside were found to cause a significant delay of central corneal wounds, 0.1 per cent idoxuridine (IDU), three drops four times a day for twelve days, resulted in no significant delay in the healing strength of central corneal wounds.*

Since their introduction into the field of ophthalmology, antiviral drugs have been used extensively for the treatment of herpes simplex infection of the cornea. Despite some early disagreement, it has been established that idoxuridine (5-iodo-2'-deoxyuridine, IDU), in its currently used concentration and dosage, is a valuable drug in the treatment of herpes simplex of the cornea. The effect of IDU (Stoxil) on the healing of penetrating wounds was previously evaluated.[1] Using an early model of our present tensiometer, a marked retardation in the healing of penetrating wounds was found when one drop of 0.1 per cent IDU was applied to the wounded eye every hour for fourteen hours, and the wound strength tested on the thirteenth postoperative day.

**Table I.** Tensile strength of central corneal wounds in rabbits treated with 0.1 per cent IDU twelve days after wounding

| *Total No. of rabbits* | *Tensile strength (Gm./5.0 mm. wound)* | |
|---|---|---|
| | *IUD (0.1%)* | *Control* |
| 17 | $\bar{x}$ 178.9 | $\bar{x}$ 187.9 |
| Standard error of the mean | ± 18.4 | ± 26.6 |
| Probability value | $P < 0.1$ ∴ No significant difference | |

It is generally accepted that 1 per cent trifluorothymidine is fully effective in the treatment of herpetic keratitis. In contrast, 0.1 per cent IDU would have to be used at least every two hours around the clock for its antiviral effect to be comparable to that of trifluorothymidine. Since IDU has already been found to markedly retard the healing of penetrating wounds at this concentration and dosage, using essentially the same method for determining the tensile strength, repetition of those studies will add little to the purpose of this study. In contrast, the effect of less intense therapy, such as IDU four times a day, is not known. Of even greater importance is the fact that while IDU is indeed used up to every two hours around the clock for herpetic keratitis, it is seldom used at this concentration when longer duration of treatment is needed, such as covering for concomitant use of corticosteroid, particularly as after corneal transplantation in eyes with previous history of herpetic infections. It is in these eyes where its effect on the gain of tensile strength is of the utmost importance.

A previously described, a well-standardized wound strength model in rabbits[2] was used to compare the effects of IDU, trifluorothymidine, and cytosine arabinoside on the tensile strength of penetrating stromal wounds.

***Materials and methods.*** A total of 42 mature albino rabbits weighing 2 to 3 kilograms (5 to 7 pounds) each were used. The pupils were widely dilated with Neo-synephrine before surgery. Anesthesia was induced by intravenous injection of sodium pentobarbital (Nembutal).

*Surgical techniques.* Standard lid retractors were used to expose the eye. A 9 to 10 mm. nonpenetrating linear incision was made through the center of the cornea. Two 7-0 silk sutures were placed about 4 mm. apart and looped out of the way.