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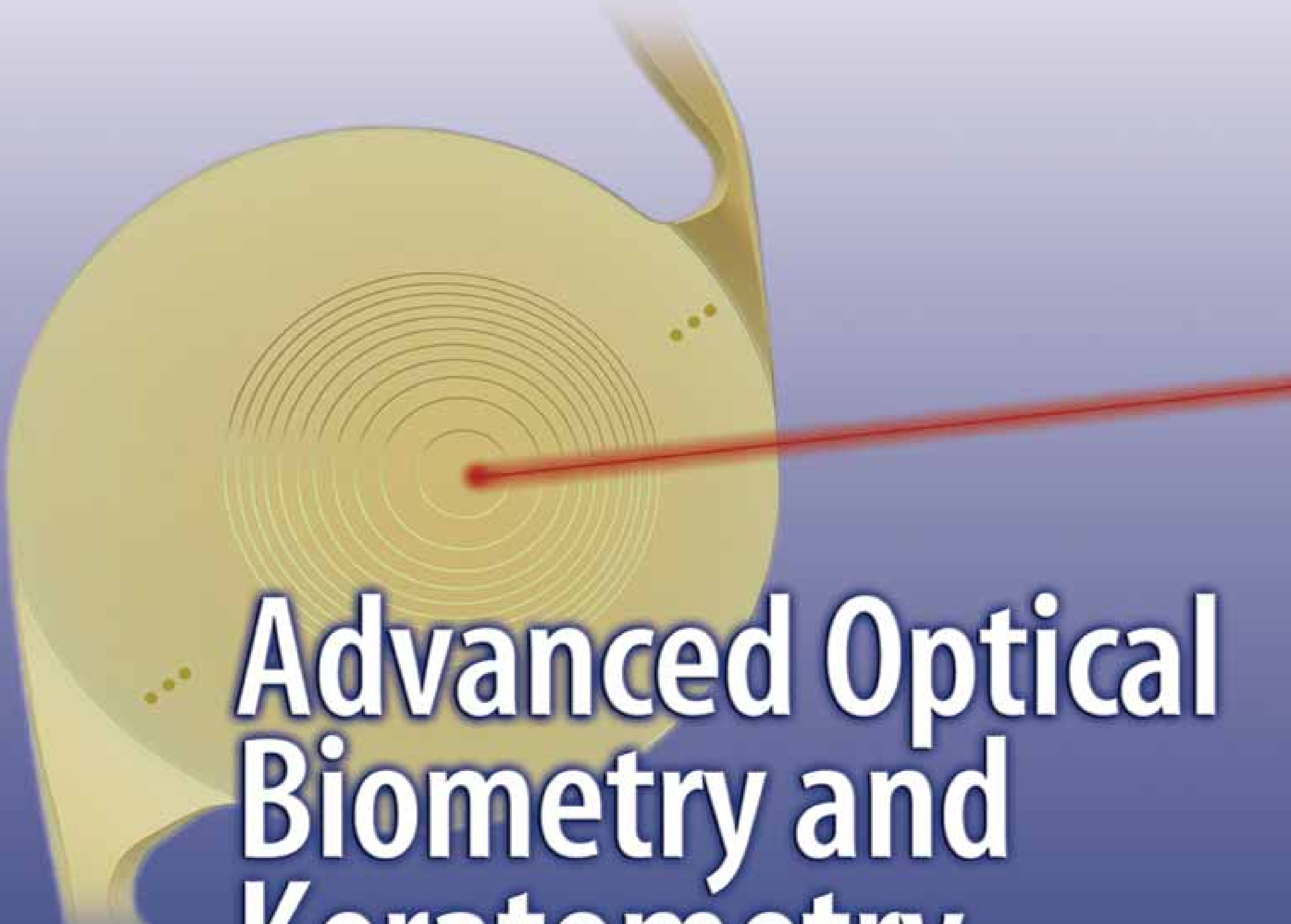
Cataract & Refractive Surgery TODAY

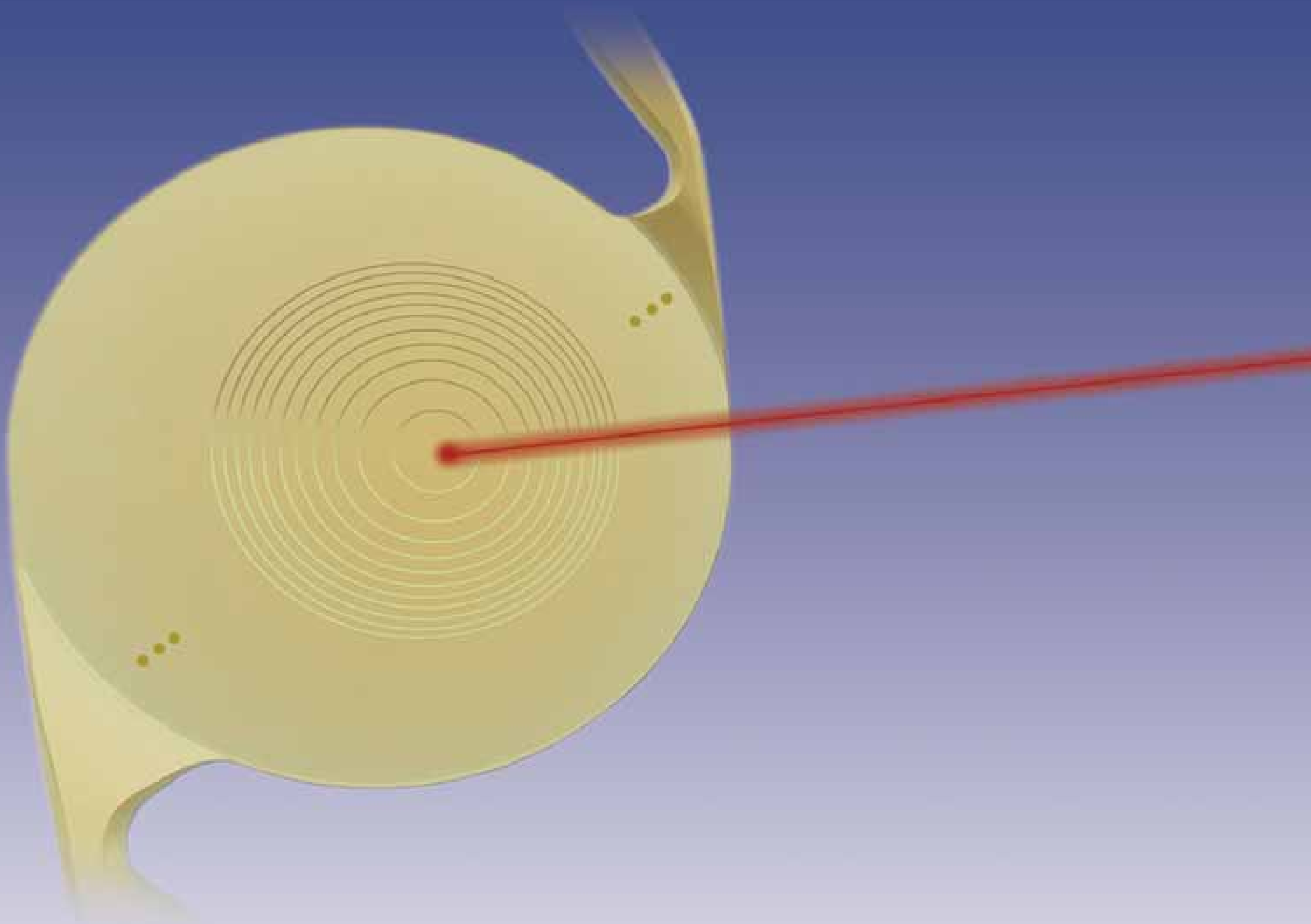
January 2011



Advanced Optical Biometry and Keratometry with LENSTAR LS 900

Comfort and confidence for all IOL calculations

Advanced Optical Biometry and Keratometry with LENSTAR LS 900



CONTENTS

Lenstar and Ray-Tracing Calculations

Using real numbers with exact ray tracing.

BY JAIME ARAMBERRI, MD

The Lenstar LS 900 (Haag-Streit International, Koeniz, Switzerland) is an optical biometer that measures distances among all optical interfaces by means of light interferometry. In comparison, IOLMaster (Carl Zeiss Meditec, Jena, Germany) only measures axial length with this technology. Lenstar variables allow the use of new IOL calculation formulas that demand more eye parameters to precisely predict the position of the IOL.

Traditional formulas such as the Haigis, Hoffer Q, Holladay I, Olsen, and SRK/T were acceptable in the past due to their simplicity and accuracy; however, in our more demanding present context—with multifocal and toric IOLs for exigency of emmetropia—many surgeons have been looking for more accurate alternatives.

Current vergence formulas present some significant drawbacks. First, paraxial calculations are precise enough as long as the corneal optics has a normal level of asphericity. However, many cases do not have normal asphericities, including patients with keratoconus or after refractive procedures such as LASIK, PRK, and radial keratotomy. Second, IOL characterization for the range of powers with a single figure (A constant) is incorrect by definition and leads to error in extreme values. Third, effective lens position (ELP) is a theoretical value that does not directly match with the measured physical distance from the cornea to the anterior surface of the IOL. Fourth, corneal vergence is calculated from the keratometry (K) value, which is based on a constant anterior-to-posterior ratio assumption when diopters are calculated from millimeters using the standard index of refraction (n=1.3375). This premise fails in some cases, like in post-LASIK or PRK corneas.

IOL position prediction accuracy varies from formula to formula, but most formulas generally perform poorly in odd cases or when the proportion between the anterior segment and total eye length is out of the normal range.

EXACT RAY TRACING

Thick lens pseudophakic eye models can be used to calculate refraction of light rays (ie, ray tracing; Figure 1) from cornea to retina using exact, nonparaxial optics. This can be done with different levels of complexity depending on how the cornea is defined: A complete elevation data set obtained from corneal topography or a second-order calculation using curvature radii and asphericity coeffients. The latter offers, in my experience, a good balance between simplicity, accuracy, and precision to achieve good refraction predictions. The only assumptions in these models are the perfect alignment between the cornea, IOL, and fovea and the absence of tilt.

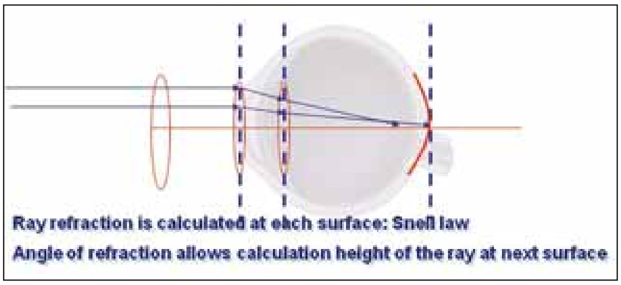


Figure 1. Exact ray-tracing calculation.

The IOL position prediction algorithm determines the level of accuracy of these formulas, estimating the pseudophakic anterior chamber depth. This can only be done using statistics on large data sets to account for the predictive power of each variable. Moreover, the formula must be sensitive to unusual proportions or magnitudes and adapt the calculation to them. The most frequent example is the post-LASIK or post-PRK eye, where the corneal anterior curvature will not fit the regression equation the way an operated cornea does.

INCREASED PRECISION

Current formulas use two variables to predict ELP. Hoffer Q, Holladay I, and SRK/T base this estimation on axial length and K readings; Haigis uses axial length and anterior chamber depth. Increasing the number of predictors—like Holladay II and Olsen have done—improves prediction accuracy but introduces more measurement error. This was significant when ultrasound biometry was the standard.

		ABS ERROR SIRIUS ASPH	ABS ERROR SIRIUS PARAX	ABS ERROR LENSTAR ASPH	ABS ERROR LENSTAR PARAX
N	Valid	78	78	78	78
Mean		0,46	0,46	0,42	0,39
Median		0,38	0,38	0,32	0,33
Std. Deviation		0,36	0,34	0,34	0,28
Skewness		0,71	0,89	1,19	1,35
Std. Error of Skewness		0,27	0,27	0,27	0,27
Kurtosis		-0,55	0,21	1,12	2,49
Std. Error of Kurtosis		0,54	0,54	0,54	0,54
Minimum		0,00	0,02	0,00	0,00
Maximum		1,31	1,52	1,45	1,52

Lenstar data achieve lower MAE

Paraxial Lenstar model scores best

Figure 2. Mean absolute error with the pseudophakic eye refraction prediction model.

		ABS ERROR ASPH SIRIUS	ABS ERROR PARAX SIRIUS	ABS ERROR ASPH LENSTAR	ABS ERROR PARAX LENSTAR
N	Valid	[illegible]	[illegible]	[illegible]	[illegible]
Mean		0,51	0,49	0,46	0,41
Median		0,45	0,46	0,40	0,33
Std. Deviation		0,33	0,35	0,33	0,32
Skewness		0,66	0,52	1,10	1,20
Std. Error of Skewness		0,28	0,28	0,28	0,28
Kurtosis		-0,22	-0,48	1,82	1,21
Std. Error of Kurtosis		0,56	0,56	0,56	0,56
Minimum		0	0	0	0
Maximum		1,4	1,4	1,7	1,48

Lenstar Paraxial model scores best

Figure 3. Mean absolute error with the Aramberri formula for refraction prediction error model.

Lenstar has increased the precision of biometry by measuring all distances with a repeatability of microns. I have developed my own IOL position prediction algorithm from Lenstar's axial length, K readings, anterior chamber depth, and lens thickness. The formula is also paired with corneal anterior asphericity, posterior radius, and corneal posterior asphericity information, which are obtained with a Scheimpflug device like the Galilei (Ziemer Group, Port, Switzerland), Pentacam HR (Oculus Optikgeräte GmbH, Wetzlar, Germany), or the Sirius (Costruzioni Strumenti Oftalmici, Florence, Italy).

Lens thickness is a remarkable parameter; it complements anterior chamber depth for the prediction of IOL position, because the same anterior chamber depth will render a different IOL position if lens thickness is different. The final—and otherwise logical—conclusion is that the distance from the cornea to the posterior capsule is the sum of the anterior chamber depth and lens thickness. Lenstar produces repeatable anterior chamber depth and lens thickness measurements, giving way to the use of these new multivariable formulas and discarding the fear of increased error propagation.

The circle is complete after surgery, when Lenstar is useful to measure the distance between the cornea and the anterior surface of the IOL. For the first time, we can trustfully compare the predicted IOL position with the actual position to determine where the prediction error (if present) is coming from.

When this type of calculation—all real measured numbers, from anterior cornea to retina and whether phakic or pseudophakic—combines with real optics, theory matches reality. Avoiding the use of empiric assumptions give us the confidence that calculations will robustly face any type of strange eyes that could show up in the future.

DATA COLLECTED

The big question is: Does Lenstar data improve accuracy? Data from 78 normal, unoperated eyes of 56 patients was collected from January to July 2010 to compare biometry (Lenstar LS 900) and corneal tomography (Sirius) measurements. The axial length in this population ranged from 20.89 to 34.35 mm, and we implanted the same monofocal IOL in every case. Biometry and corneal tomography were performed pre- and postoperatively. All eyes had a BCVA of at least 0.80 so that final refraction could be accurate. The variables for analysis with the Lenstar were phakic axial length, phakic anterior chamber depth, phakic lens thickness, and phakic K readings as well as pseudophakic axial length, pseudophakic anterior chamber depth, and pseudophakic K readings. With the Sirius, the variables for analysis were anterior and posterior radius, anterior and posterior asphericity, and corneal thickness.

I used two models, the first of which is the pseudophakic eye model refraction prediction error model. Pseudophakic anterior chamber depth was measured with Lenstar. This model shows the best-case scenario for pseudophakic eye refraction prediction, where the only errors come from measurement error propagation or from assumption errors (ie, IOL tilt or decentration). The precision we achieve once IOL position prediction error is eliminated—or substituted by IOL position measurement error if we are accurate—is astounding.

The second model, the Aramberri formula for refraction prediction error, predicts where the IOL will sit in the eye using preoperative measurements. This is a multiple regression formula with four predicting variables (axial length, anterior chamber depth, K readings, and lens thickness) for the main regression equation and three corneal variables (posterior R, posterior Q, and anterior Q) to adjust the prediction if any abnormal proportion is detected.

In both models, paraxial and exact ray-tracing calculations were performed to determine the effect of introducing spherical aberration on the final results.

RESULTS

The accuracy of pseudophakic eye model refraction prediction was influenced by axial length (IOL power). Short eyes tended to be slightly overestimated (myopic shift) and long eyes slightly underestimated (hyperopic shift).

As it is logical in short eyes with high IOL powers, the aspheric calculation is more accurate; in mid-range and long eyes, paraxial calculations are similar or sometimes more accurate. As a whole, mean absolute error (Figure 2) was 0.39 ±0.28 D for the paraxial model and 0.42 ±0.44 D for the aspheric model. In the paraxial group, 69.2% of eyes where within ±0.50 D of prediction error and 94.9% within ±1.00 D. In the aspheric group, 70.5% were within ±0.50 D and 91% were within ±1.00 D. Standard deviation was higher (0.55) in very long eyes.

With the Aramberri formula for refraction prediction error, the same pattern could be found, where the IOL power is overestimated in short eyes and underestimated in long. The nice surprise was that prediction error (Figure 3) did not increase dramatically when IOL position prediction was introduced. As a whole, mean absolute error was 0.41 ±0.32 D for the paraxial model and 0.46 ±0.33 D for the aspheric model. In the paraxial group, 69.9% of eyes where within ±0.50 D of prediction error and 93.2% were within ±1.00 D. In the aspheric group, 60.3% were within ±0.50 D and 94.5% were within ±1.00 D.

CONCLUSION

Lenstar has increased biometry precision for IOL calculation tasks, measuring all optical interfaces within the eye by optic interferometry.

The combination with exact ray-tracing calculations and new IOL position prediction formulas improve IOL calculations significantly, fulfilling the demand of both surgeons and patients. More research is necessary to validate this formula in different settings and all type of eyes before it is made available to other surgeons, but its performance looks promising. ■

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Pearls to Improve IOL Power Calculations

Use anterior chamber depth and lens thickness measurements with the Lenstar LS 900.

BY THOMAS OLSEN, MD

The Lenstar LS 900 (Haag-Streit International, Koeniz, Switzerland) is changing the way we use IOL power calculations. The software developments available with this new model include optical biometry for all intraocular distances, providing high-definition measurements of the anterior segment including the anterior chamber depth and the lens thickness.

One of the largest benefits of the LS 900 is increased accuracy of power calculation for normal eyes as well as special cases like after laser refractive surgery. Typically when we talk about normal eyes, we classify them as normal-sized eyes with an average length. However, the more we understand the internal structure of the eye, the more variety we see. For instance, a normal-sized eye could have a thin lens but a deep anterior chamber.

PEARLS

No. 1: Break down the sources of error. The first step to improving IOL power calculations is to understand how the sources of error arise. First, consider the axial length. These errors have decreased a lot with optical biometry. Second, you can have errors in the keratometry (K) readings. One error is with the keratometer itself. If the K reading uses 1.3375, the error is approximately 0.75 D in the average case if not corrected for by the formula. Another example is post-LASIK cases, where normal corneal models do not apply. Third, there are errors in the prediction of the postoperative position of the IOL (the postoperative anterior chamber depth). When using interferometry, the source of error from the axial measurements decreases, resulting in a relatively large source of error in the estimation of the anterior chamber depth. This is perhaps the most important source of error, depending on the formula. These sources of error can be added together in an error propagation model.

No. 2: Use optical biometry. I believe every surgeon should use optical biometry because it is more precise than ultrasound. We now have 10 years' experience with optical biometry, and in my hands this has changed my work completely. To summarize, our mean absolute error decreased from approximately 0.60 D with ultrasound to less than 0.50 D with optical biometry.

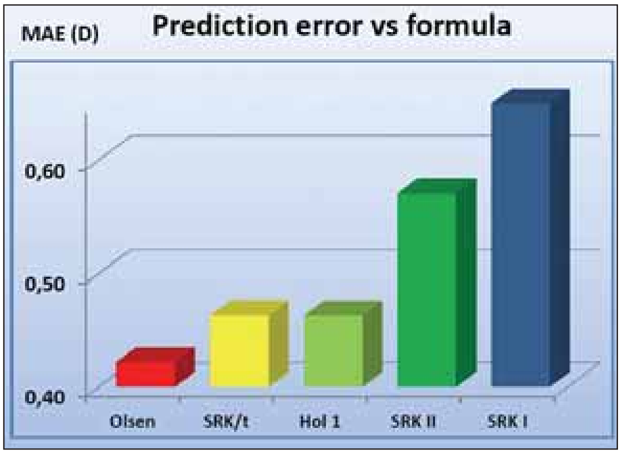

Figure 1. The improvement of prediction error with the Lenstar over existing methods.

The old IOL power calculation formulas used only K readings and axial length for the entire process of calculating the effective lens position as well as the refractive outcome with a given IOL power. We now have overwhelming evidence that the postoperative anterior chamber depth depends on more than just the K reading and axial length. The key to success is really an improved prediction of the anterior chamber depth, and here the anatomy of the anterior segment appears to be more important than we used to think.

No. 3: Compensate for refractive errors. You must always measure outcomes. To determine the distribution of refractive errors, look at the offset value and compensate for this error by applying a constant to your method. Remember that these factors are virtual constants; they are not physical-based.

We can go even further by using thick lens formulas and ray tracing. My own approach from the beginning has been a thick lens approach, but we are now playing with ray tracing as well, which has some advantages when dealing with nonspherical surfaces. We use physical information for all surfaces, which is important for post-LASIK patients. Then I incorporate the true anterior chamber depth, not a virtual distance, into the formula. A trial version of our approach can be found at www.phacooptics.com.

No. 4: Calculating the IOL power in the eye. The LS 900 can also be used to measure the IOL power within the eye, which is useful in the event of a refractive surprise. Calculating the power of the IOL in the eye is easy if you have all of the refractive data, including the actual anterior chamber depth, which can also be measured with the LS 900. In addition to remeasuring anterior chamber depth, investigate the optic configuration of the implanted IOL. The next step is to back calculate from the information you have gathered to figure out the IOL power in the eye.

PREOPERATIVE PREDICTORS

Today, along with the improved biometry, we can implant an IOL into the capsular bag in a standardized way after creating a standard-sized capsulorrhexis. There is little room for surgeon factors to account for, as the only thing that matters is the physical position of the implant after surgery. However, we must take a closer look at the anterior chamber depth prediction. If we take 3,000 cases and calculate the postoperative anterior chamber depth in every case, what we notice is that there is a strong dependency on preoperative anterior chamber depth as well as the lens thickness.

As more predictors are added, the prediction of anterior chamber depth gets more accurate, and therefore multiple variable prediction algorithms have the lowest prediction errors. One important point is that such prediction algorithms provide a calculation with no bias for the axial length, and thus a low error in short as well as in long eyes. The nice thing about the Lenstar LS 900 is that the anterior chamber depth, axial length, and lens thickness measurements are all accurate.

The axial length and the K reading are no longer the only variables needed to predict the postoperative anterior chamber depth, and therefore these measurements can be removed from the prediction formula in some cases. This is of great help when dealing with post-LASIK cases where the K reading is far from the normal value and is useless in the algorithm predicting the postoperative anterior chamber depth.

CONCLUSION

Improved anterior chamber depth prediction with the Lenstar LS 900 can give you a mean absolute IOL refractive prediction error of 0.41 D, which is significantly better than with other methods. If you count the number of cases within ±1.00 D, we are well over 95% of cases. I have to add that these figures were based on busy University Clinic data, and I do believe that better results can be obtained in a more controlled environment. Optical biometry with the Lenstar LS 900 is a promising tool for superior IOL calculation. ■

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The Importance of Keratometry Readings

Two surgeons discuss measurements with the Lenstar LS 900.

BY DAVID L. COOKE, MD; AND UDAY DEVGAN, MD

Devgan: I have been noticing, David, that the biggest challenge in nailing a plano refraction after cataract surgery is preoperative keratometry (K) values. Axial length measurements are accurate, capsulorrhexis creation is uniform, and incisions are consistent. However, it is that variability in measuring K that keeps us from plano. For every 1.00 D my preoperative K is off, there is about a 1.00 D refractive surprise.

> "Lenstar was, without question, the most accurate for astigmatism axis and power."
> — David L. Cooke, MD

Cooke: There is no question that K readings are an issue. From my perspective, the biggest factor is astigmatism. Readings with the IOLMaster (Carl Zeiss Meditec, Jena, Germany) and the Lenstar LS 900 (Haag-Streit International, Koeniz, Switzerland) are essentially the same as far as the sphere; however, when you look at astigmatism, the Lenstar nails it.

Devgan: Do you use that to judge your degree of astigmatism or the meridian for a toric IOL?

Cooke: It depends on how reliable the measurement is. If the patient has a poor tear film, the readings probably will not be reliable. The Lenstar gives a standard deviation on every measurement. If the standard deviation on the axis is within 3.5º, you can count on the measured cylinder to be accurate. When I align the toric lens with this, I have been right on the money.

Devgan: That's great. In terms of spherical lens power, I measure closer to the corneal center. With older machines or manual keratometers, we used a 4.0- or 3.5-mm peripheral zone to estimate the center. However, these technologies did not record the central power accurately in post-LASIK eyes due to the more peripheral rings. I think one of the nice things with the Lenstar is that it provides more readings. It has two rings—one being 1.65 mm in diameter and the other 2.3 mm in diameter—and each one has 16 points of measurements, equaling 32 points of measurements. This compares favorably over the IOLMaster, which has six points at a 2.5-mm zone. The two rings of the Lenstar are also set a lot closer to that side of the cornea, which is ideal.

I have noticed that the quality and consistency of K readings with the Lenstar are superior in post-LASIK eyes. David, have you noticed a difference in K measurements from the IOLMaster compared with the Lenstar?

Cooke: I have noticed that my K's are more consistent with the Lenstar. We analyzed K readings in 22 patients with the Lenstar and IOLMaster. We checked four readings on each machine for each eye, and the standard deviations for spherical power, axis, and power of astigmatism were all better with the Lenstar.

Devgan: I have heard that some surgeons use the IOLMaster for power calculations when implanting a toric lens or creating limbal relaxing incisions (LRIs) but use topography or manual K readings for the axis of the lens or the LRI. How does this apply to the Lenstar?

Cooke: I agree with using the IOLMaster for the power but I prefer the Lenstar for astigmatism. We compared refraction in eyes with and without astigmatism, and results showed that the Lenstar was, without question, the most accurate for astigmatism axis and power.

Devgan: We found something similar. At my practice, approximately 30% of cataract patients have already had corneal refractive surgery—mostly LASIK but some radial keratotomy. The big challenge in these patients is measuring central corneal power. Central corneal measurements are more accurate with the

Lenstar than they are with the IOLMaster. The difference is not huge, but every little piece makes an incremental difference in the end, especially in postrefractive eyes.

I also like the ability to go back and look at the quality of the measurements.

Cooke: You can also look at the images of all the lights in the two rings to see if there are distortions, and you can repeat those or delete the one that is distorted.

Devgan: Certainly. Each of the five measurements is a different color, so you can pick and choose which you use and which you delete. Out of habit, I replace the ones I delete with more measurements.

PACHYMETRY

Devgan: Another benefit of the Lenstar is that it can measure the true lens thickness and the corneal thickness.

Cooke: I use corneal thickness a lot for glaucoma, because knowing the central corneal pachymetry is now an important part of glaucoma management.

Devgan: In most normal virgin eyes, the central corneal thickness is not as crucial, but there are few subsets of patients where it helps. If the patient has previously undergone cataract surgery or if he or she has guttae, their corneal thickness could be significantly above the mean. These are indications for me to take the step of getting an endothelial cell count. Eyes with Fuchs dystrophy have endothelial dysfunction, and therefore you may see a thick cornea (600–650 µm). Another subset is post-LASIK eyes, where I want to ensure that there is enough residual stroma for a retreatment should it be necessary. A corneal thickness of 300 µm means that I may not be able to perform an excimer ablation enhancement after cataract surgery.

I think measuring the central corneal thickness does give me some benefit. Even for a virgin eye in which I will use LRIs, I know that patients with a thin central cornea will have a thinner-than-average peripheral cornea. On the other hand, I expect the periphery to be thick if the central cornea is thick in a virgin normal eye. In these cases, my LRIs would not have the same effect. I would have to do a slightly deeper and longer or more central cut to get that same effect. There are people who say that LRIs are so variable in their response. What is variable are the corneal thickness and biomechanics.

LENSTAR ALLOWS DATA QUALITY CHECKS AND ADJUSTMENTS

Cooke: Do you do your own measurements or do you have someone do them for you?

Devgan: Both, depending on what staff I have. Some are still learning. One of the nice things that I found is that, if we get five different measurements, we can go back and look at the quality of data.

Cooke: I have trained my staff to do that, and they print out any odd measurements for me to review.

Devgan: I had an interesting cataract patient referred to me from a retina specialist. The patient had a tractional diabetic macular detachment. My tech alerted me that the Lenstar measurements did not look quite right. I calculated the axial length and normal retinal position using the Lenstar, and I shifted the gate because after I did the cataract the patient was going to undergo vitrectomy. Is it as important to you to be able to look at the pure data?

Cooke: I like looking at data to get a general sense of quality of the rings and of the cornea. But I also like that it gives standard deviations for every measurement. We are studying which standard deviation in the cornea makes the most difference. It looks very likely that if the standard deviation on the axis is less than 3.5°, you can count on those K's for astigmatism as well as axis.

Devgan: I am also a big proponent of looking at the data, because whatever happens during surgery is always the surgeon's fault. I use the carpenter's rule: Measure it twice and cut once. With the Lenstar, we are measuring at least five times and then cutting once. I like to look at data because, more than anything else, nailing that postoperative refraction is the surest way to deliver happiness. I know that good data and good calculations produce good results.

Cooke: What do you think is the biggest area where there is a problem?

Devgan: In most eyes, I would say it is K measurements; however, in unusual eyes such as very short, very long, or staphylomatous eyes it would be axial length.

Cooke: For 95% of patients it is the cornea, and that is where I trust the corneal readings better with the Lenstar.

LENSTAR SCAN RESEMBLES ULTRASOUND A-SCAN

Devgan: I treat a lot of white, dense cataracts, particularly when I teach the ophthalmology resident surgeons at Olive View UCLA Medical Center. When we take A-scan measurements of these eyes, it is easy to locate the data spikes that delineate the anatomic structures, such as the cornea, lens, and retina. One nice thing with the Lenstar is that the data presented is in this same format, with specific spikes that locate these ocular landmarks. These are easy to interpret, and the gates can be shifted. This technology is also easier for our techs, who are used to doing ultrasound. Now they have a machine that calculates measurements optically, but I get the same readout and the same pattern as I would from a proper A-scan. Being able to shift the gates is probably the best thing you can do in these unusual eyes.

LENSTAR PUPIL DIAMETER

Cooke: The Lenstar gives a lot of data, and I don't know how to use all of it. Do you use the pupil diameter, and if so, can you teach me what it is helpful for?

Devgan: I do use the pupil diameter, and here is why: Multifocal lenses have optical zones that require an optimal pupil size for optimal function. Even pupil centration is important, because the lens must be well centered in the pupil—not the capsular bag.

With the Lenstar, you can measure this ahead of time to determine if the patient has a pupil that is decentered or if the center is off by 1.0 to 1.5 mm. It seems that the better the multifocal lens is centered on the pupil, the better the visual results will be. This may not be as rigid for monofocal lenses, but even with toric IOLs we want the bowtie of corneal astigmatism to be aligned with the astigmatic power of the implant optic.

> "I have recommended toric IOLs more frequently now that I am convinced that the Lenstar is accurate."
> — David L. Cooke, MD

Cooke: We also tested machine astigmatism accuracy by comparing the results of five machines with a careful subjective refraction in an eye with no other astigmatism (the patient already had a monofocal IOL). The Lenstar was the most accurate for both cylinder power and for cylinder axis. Based on our studies, there is no question that the Lenstar is more consistent and more accurate than other technologies. I have recommended toric IOLs more frequently now that I am convinced that the Lenstar is accurate. This is because my confidence level has risen. ■

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Improving Toric IOL Power Calculations With the Lenstar

Two surgeons discuss the future possibilities.

BY WARREN E. HILL, MD; AND H. JOHN SHAMMAS, MD

Shammas: What is your preoperative routine, and more specifically, how do you know where to put the toric IOL?

Hill: The first thing we do is obtain a topographic map to confirm that the astigmatism is regular, followed by calculating the spherical power of the IOL. Next, we typically use Javal keratometry to see if the magnitude of the axis of astigmatism qualifies the patient for a toric lens. Unexpectedly, we have begun to find that the Lenstar (Haag-Streit International, Koeniz, Switzerland) and the Javal keratometer provide almost the same information and that the Lenstar's keratometry (K) readings correlated nicely with the astigmatism we are looking to correct at the plane of the capsular bag. Since making that observation, we have begun to use Lenstar K's to calculate the power difference between principal meridians and the steep axis for the toric IOL. Additionally, we have found that these K readings are consistent and accurate for calculating the spherical power of the IOL. Even though we use the Holladay 2 formula, we noticed that our outcomes have tightened since we started using the Lenstar.

Shammas: The K's are quite precise and reproducible, and it has made such a difference that I use Lenstar K readings automatically for my calculations unless there is major astigmatism. I still do topography if I am using a toric IOL, but the measurements fit in exactly where I want them to be for spherical power, estimated astigmatism, and axis of the astigmatism.

Hill: This is the first automated instrument that we found to be reliable enough to use with toric IOLs. When we do the same measurement multiple times, the reproducibility is probably the best that I have seen. For the newer-generation formulas such as Haigis, Holladay 2, and Olsen, measuring anterior chamber depth and lens thickness has become important for formula accuracy. Do you agree?

Shammas: The nice part about the Lenstar is that it measures anterior chamber depth in the optical axis, and it is the most accurate way of measuring that. For the Haigis formula, which relies heavily on anterior chamber depth, the accuracy of the Lenstar is a great improvement on the way we use the formula. If you transition to the Holladay 2, the Olsen formula, or any of the more modern formulas that require a more accurate anterior chamber depth and lens thickness, no other instrument can compete with the Lenstar.

Hill: An important aspect of moving to the next generation of formulas has to do with the measurement of anterior chamber depth, and to that some have added lens thickness and horizontal corneal diameter. Who knows what variables we will add in the future.

Shammas: And not only that, but the possibilities that we have with the Lenstar not only lie in the measurement of the axial length, anterior chamber depth, and lens thickness, but we can now estimate where the implant will sit after surgery by measuring the distance between the cornea and the IOL. This will become so accurate that it will lead to a new generation of formulas to improve our accuracy.

Perhaps maybe one day, instead of talking about the estimated lens position in abstract numbers, we can go back to exactly that measurement where the implant is sitting and we can do ray-tracing formulas. The Lenstar will be a useful tool to improve IOL power calculations, whether it will be through Gaussian optics or through ray tracing. Studies have shown that Gaussian optics and ray tracing give the same results, but once we learn where the implant is sitting exactly, maybe we can fine-tune the results and know exactly where we get it. ■

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