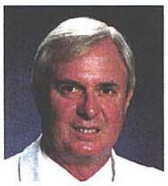
Experts discuss the benefits and problems of various videokeratography technologies and their potential clinical applications.

EW Dialogue

EW DIALOGUE:
Placido vs. nonplacido disk videokeratography

ABOUT THE PARTICIPANTS



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Stephen D. Klyce, PhD: Today, we'd like to discuss what the future is going to bring, in terms of technology to measure corneal topography, and try to focus on ways to measure topography, other than Placido disk technology.

There are four different approaches currently being used. The Placido disk approach, or videokeratoscopy, interference technology, fluorescein profilometry, and the new technology of using images of scanning slits across the cornea to measure the cornea's front and back surfaces. With the development of laser in-situ keratomileusis, measurement of the back surface may, in fact, turn out to be critical.

Scanning slit: Accuracy and reproducibility

Steven E. Wilson, MD: In the past, many have called for studies validating the Orbscan and other corneal topography instruments. I think we've been able to get away with not doing that in a rigorous manner, because we weren't looking for accurate measurements with a lot of these instruments; for example, to link the excimer laser to corneal topography.

I think we're coming to a time where this will be critical, and we'll get to see how accurate the information is. Because if it isn't accurate, the ablations we get with this attempt at linkage will be not optimal. I think we're going to get the evidence we need regarding reproducibility and inaccuracy for the scanning slit and other technologies.

Jack T. Holladay, MD: I've been a consultant for Orbtech for about 3½ to 4 years and have been on their research team to try to get their accuracy and repeatability at a level we need.

Up until about a year ago, I would have told you that the repeatability and accuracy weren't good enough to use clinically. That was because the slitlamp data and the Placido data were not integrated.

So about a year ago, the research team took the height data, which was very good from the slit, and integrated it with the Placido data, so you could take the best of both and eliminate the noise and discontinuities.

For example, if you take a cornea, take a trephine and cut a 3-mm button, then raise it up 2 mm, Placido disk technology can't recognize it, because you get the same curvatures when you look along the optical axis.

Today, you get the best results with the height data from the Orbtech. In contrast, its Placido data is about half as accurate as the topography data you get from all the other companies, because moving a Placido in front of a cornea makes it much harder to get repeatability and stability.

Maureen K. Lundergan, MD: I would echo most everything that Dr. Holladay has said. The Placido information on the newest version of the software is, far and away, more accurate than it was.

But the elevation data, I think, are very accurate. I can usually see where the problem lies when a patient comes in with a subjective suboptimal outcome, in spite of what appears to be a normal Placido map.

Tetsuro Oshika, MD: I tested the diopter data, not the elevation data, of the Orbscan and found that the repeatability was not very high, but rather reasonable when we compare the data of anterior surface with those of Placido-type topography. Regarding the posterior surface, similar comparison was not possible since there is no other means to measure the back corneal surface, but the reproducibility seemed acceptable.

I think it has a definite application in three fields.

- The first is the evaluation of the posterior surface elevation — detection of the iatrogenic posterior keratectasia and detection/screening of subclinical posterior keratoconus before surgery.
- The second field is the pachymetry map, in which you can obtain pachymetry data of the entire cornea. This is useful because the thinnest portion of the cornea may not exactly correspond to the pupil center, visual axis, or videokeratography axis.
- The third is the calculation of true corneal refractive power. Especially after refractive surgery, the conventional keratometric index of refraction is not accurate, because the anterior/posterior ratio of the curvature has changed. The Orbscan is able to assess the anterior and posterior curvature separately.

Thomas Kohnen, MD: I'm very happy to hear Dr. Holladay reporting about the Orbscan system's reproducibility and accuracy, and we have to prove this. When we start these studies, we still want to compare them with Placido-based units. We should not convert to his technology without appropriate research.

Noel A. Alpins, MD: I think that when I first examined the Orbteck machine, probably about 5 years ago, the differentiation was made about how important it is for a topography-guided ablation and how much better this machine might be over the Placido-type machines for examining the details of the corneal shape. But I think this differentiation has become less pronounced.

The idea of a totally topographically guided laser or a totally refractively guided laser is in danger of producing adverse outcomes. At one extreme, if you go purely for a spherical-type cornea based on topography, you are going to be leaving some refractive astigmatism. And when you change the refraction employing topography parameters alone, the ratio of the keratometric change to the refractive change, in the spherical sense, is not necessarily a one-to-one ratio so this can frequently suffer from problems of predictability and result in a refractive surprise.

And the other extreme, whether the laser is guided by the spectacle refraction or wavefront technology, which is basically just another more complex refractive number, some secondary adverse topographic results may remain.

Keratectasia

Holladay: One other thing about the Orbscan: I think they're playing up the posterior surface a little more than they should. This posterior bowing that people came up with first was an error in the analysis. Because when one picture is compared with another, the vertex of the corneas is staked, which means that if you take your postop map and put the corneal vertex where it was preoperatively, the pachymetry tells you that it's that thick.

If the cornea is 100 µm thinner and the anterior vertex is at the same point, the cornea must have bowed forward by the thickness of the ablation. But it was purely because they staked it at the wrong place. It should have been staked at the limbus and then there would have been no bowing or anything else.

Kohnen: I'm not sure if Dr. Holladay was referring to the recent paper that came out in *Ophthalmology* (Wang Z, Chen J, Yang B. Posterior corneal surface topographic changes after laser in-situ keratomileusis are related to residual corneal bed thickness. 1999;106(2):406-409), where they showed that in ectasia of the cornea, the amount of bowing forward was about 20 µm. The accuracy of the machine is only about 20 µm, so you might say there might be a trend there. But to draw conclusions from the data is not possible, which the reviewer, Robert Maloney, MD, pointed out.

Klyce: I'd also like to say that it's very important that we be able to appreciate whether or not these refractive surgical procedures are producing a keratectasia of the cornea, a pseudokeratectomic-like figure. There's at least one paper that shows some very noisy Placido disk topographies of a patient who supposedly developed a keratectasia following, I believe, it was LASIK. And I just want to caution all of you and the readers of *EyeWorld* that you have to be very careful in interpretation of a noisy signal.

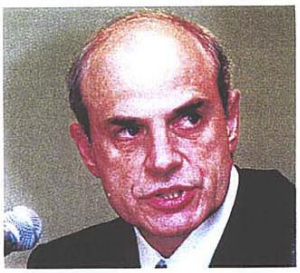
Lundergan: I think we have a tremendous amount to learn about the posterior cornea and its contribution.

The posterior information is really important, preoperatively and postoperatively. And it's still valid to look at that information preoperatively, combined with all the other information. If you have an overall steep cornea without a frank area of ectasia, an overall thin cornea, and a posterior cornea that has a 55-D best-fit sphere, that's a red flag.

I think it's still useful to use your first postoperative map and compare that to the postoperative posterior corneal elevation maps to define whether you are developing ectasia as opposed to regression. If you see a trend toward anterior movement of the cornea or steepening of the posterior cornea along with a refractive change, without a significant change on the anterior cornea, you might worry about an early corneal ectasia.

Holladay: If you have ectasia, you must have a thinning, by definition. When you add, all you do is you take the anterior surface Placido and subtract the pachymetry to get the posterior surface. So, the noise and height data from pachymetry are going to give you a posterior surface that is just a reflection of the front minus the height data.

The only thing that thickness is going to do is mechanical. The back surface power is 10 times less effective than the front surface power. The front surface is 50, the back is minus –5. So, comments like, "You may have astigmatism on the back surface," are questionable. You have to have 10 times the amount for a 0.5 D of astigmatism to match 5.



Ronald R. Krueger, MD: First, there probably is keratectasia being seen in some patients. There are at least three articles published suggesting this. One of the ways that ectasia seems to be coming up is that it looks like a steep central island, but really, it's not, because it is progressing.

How do we know something's a steep central island vs. how do we know it's ectasia? A steep central island is there right away after surgery and tends to dissipate a little as time goes on. An ectasia will display a normal map and then, over months and maybe even a year, you're going to see some kind of a central bulging.

Calibration

Krueger: I guess I question the resolution issue. I'm known by the Orbscan people to have the thickest cornea in ophthalmology. I've been measured at about 670 or 680 µm with the Orbscan and subsequently had ultrasonic pachymetry done which I believe is the standard by which we measure thickness clinically and this measured around 600. Is Orbscan right or is ultrasonic pachymetry right?

I know that we've done radial keratotomy for years and if you set the blade an extra 70 µm more, you're going to perforate every time. So I would tend to think ultrasonic pachymetry is right.

Klyce: The calibration issue has come up before. You've mentioned that the standard for measuring thickness was acoustic. I disagree. The gold standard, I always felt, was optical pachymetry. And the only reason that optical pachymetry didn't succeed is that when used manually, it's very difficult to teach or do well.

But now the Orbscan unit is calibrated. This is a calibration issue, not technology pluses and minuses. The Orbscan, I think, is calibrated so that it reads a central corneal thickness in humans of about 560 µm, somewhat higher than acoustic measurements.

Holladay: And they've addressed that in the last year. You couldn't trust the pachymetry data and it was within 100 µm; it depended on where the scan, your eye, the reflections, and lots of other things were, so it was clearly off by 70 µm.

If you do optical pachymetry and can use it, it is within 5 µm. And for somebody who can't use it, it's within 100 µm. So you've got to learn how to use it first.

Right now, you can get about 5-to-8-µm repeatability and accuracy with an ultrasonic pachymeter. It's about twice that for the Orbscan.

Other approaches

Klyce: Any comments about fluorescein profilometry?

Holladay: I don't think it's possible to get the accuracy you get with Placido disk. The one nice thing about Placido is that the transfer function of the reflected image, as well as the refracted image, can be exactly related. It allows you to get a quality comparison of the surface of the cornea that slit scanning and projected grids can't do.

Klyce: I agree with what Dr. Holladay has said. I'd just like to add that the basis for what he said is that there's a large refractive index gradient across the anterior surface of the cornea, so you really have to know curvature there well. You have to know it better than you know the posterior surface curvature, because the gradient and refractive index across the posterior surface are very small. Height data probably do an adequate job for the back surface measurement of corneal power.

Let's talk about interference techniques for measuring corneal shape. There was a machine that used phase-modulated laser holography to attempt to measure the cornea's surface. This was very exciting technology, because it had the capability of being the most accurate measuring device, even more accurate than the Placido technology. But it never succeeded.

Wilson: Of course, all of us would expect that technology to have the potential to be the most accurate. But, in fact, with the instruments that were available for us to look at and play with on the floor of the Academy and other meetings, I was impressed that the reproducibility of that particular instrument was the worst I'd ever seen. I would go back day after day and have my cornea measured and the image was never reproducible.

Holladay: I disagree. It was the same thing we went through with topography, in that if the eye is not in the same position every time you take that picture, you get a different answer. The aiming and alignment systems are manual. It's all because the patient's not in the same position.

Wilson: I think we need some type of reference to be able to validate these instruments. They all will try to link ablation and making custom corneas, so we'd need to have some type of reference surfaces or structures, in the case of instrument like the Orbscan, to fine-tune the accuracy and reproducibility.

Klyce: A number of companies have been participating in the development of standards for corneal topography. The American National Standards Institute Standards Committee is headed by Charles Campbell, of Humphrey Instruments. They are coming close to formulating standards that include definitions in the field and the standard shapes each of these machines should be calibrated and tested with to comply with these standards.

Topography-guided ablations

Klyce: We've mentioned topography-guided laser systems a couple times. Is Placido disk technology adequate? Is that the best we should be doing in measuring or should we be doing retinal mapping as Autonomous Technologies has been attempting to do?

Krueger: First of all, you must have great resolution and secondly, you must have repeatability.

The biggest problem with topographic-guided ablation right now is taking that corneal map, accurate or not, and linking it to the eye. Because cyclotorsions or little centration issues could completely throw it off. Once we overcome that, we're going to see some real promising results.

Holladay: I agree. But I would point out one thing about spatial refractors, which is what we're talking about — basing it on refraction.

The first is that in patients who end up with an irregular astigmatism that's not corneal, it's in the crystalline lens; that's cataract formation. If you really get to the irregular maps that are not corneal, you're going to end up fine-tuning that about every 3 months as that cataract changes and that's the only process that really ends up giving you irregular astigmatism that is not corneal.

Now, in terms of people who were born with lenticular astigmatism, if you do a spatial refraction on them over a year or two and it's doesn't change, then you can use the spatial refractor to guide the ablation.

Alpins: Topographers give you the simulated keratometry, a kind of vectorial average between the cornea's two hemi-divisions. What we need is a simulated keratometry value for each half of the cornea.

I mean, at present, you need to look at the background information of these machines. There's a set of 3-mm, 5-mm, and 7-mm values and you might have to compromise and take a 5-mm value and call it the average for that half of the eye. But what the companies should be putting out for you is an average keratometry for the eye and a separate simulated keratometry value for each of the two parts of the eye. Once you have a value for each part of the eye, you can start determining the amount of corneal irregularity in the numerical sense. You can calculate a vectorial value (the topographic disparity), which is a measure of corneal irregularity that can serve as a very useful standard common to all topographers.

Future developments

Klyce: Does anyone want to say anything about what they see in the future?

Alpins: As I look down the laser's microscope prior to treatment, I'd like to be able to see that eye with a real-time topography image on it, so I can accurately align the laser beam during surgery. This would enable a topography picture to identify the steepest corneal axis under the laser and improve accuracy of treatment application.

Kohnen: What I'm missing is a kind of standard. There are so many variables and nobody's really standardizing this. That has to be done in order to move forward.

Krueger: I really don't think topographic-guided ablations are going to treat normal corneas, because we just can't follow eye movements. I mean, unless you use a tracking system that can follow saccades perfectly, you're going to create more irregularities than you're trying to treat.

Wilson: I think we're looking at what I like to call snapshot linkage of a single map and linking ablation to that. I think we really want to go to intermittent monitoring of topography during an actual ablation. Of course, the gold standard is constantly monitoring the change being produced by the laser. I think that's a long way off.