Influence of ophthalmic viscosurgical devices on intraoperative aberrometry

Samuel Masket, MD, Nicole R. Fram, MD, Jack T. Holladay, MD, MSEE

PURPOSE: To determine whether the presence of an ophthalmic viscosurgical device (OVD) in the anterior chamber influences intraoperative aberrometry and the suggested intraocular lens (IOL) power.

SETTING: Advanced Vision Care, Los Angeles, and Specialty Surgery Center, Beverly Hills, California, USA.

DESIGN: Prospective interventional case series.

METHOD: Eyes scheduled for routine phacoemulsification and were divided into 6 equal groups, with each having 1 of 6 OVDs. After cataract removal, carefully controlled aberrometry was performed with the anterior chamber filled with balanced salt solution (BSS). Immediately thereafter, the BSS was replaced by 1 of the OVDs and the aberrometry repeated. The IOL power was selected from the BSS reading, and clinical manifest refraction was performed 3 weeks after surgery. The mean absolute error (MAE) was determined and compared with the extrapolated refraction had the IOL power been selected from the aberrometry reading under OVD.

RESULTS: The study comprised 120 eyes, 20 in each group. The IOL power determination was lower with OVD filling the chamber. For Discovisc and Amvisc Plus, the MAE determinations were statistically different because the suggested IOL power was approximately 0.50 diopter less than with a BSS fill. For the remaining OVDs (Amvisc, Healon, Healon GV, and Provisc), the MAE differences were insignificant. The strong correlation between differences in the index of refraction between BSS and specific OVDs appeared to be causal.

CONCLUSION: Surgeons should be aware of the influence of OVDs on the accuracy of intraoperative aberrometry because specific agents can alter the optical results and suggested IOL power.

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There is significant interest in the refractive outcomes of cataract surgery. Cataract surgery is often compared with laser vision correction (LVC) by patients who anticipate spectacle-free vision after cataract surgery. However, the accuracy of refractive outcomes for cataract surgery lags behind that of LVC.[1,2]

Intraoperative aberrometry has been proposed and used to aid the accuracy of intraocular lens (IOL) power selection at cataract surgery.[3] In general, aberrometry is performed after the completion of cataract removal, accomplishing an aphakic refraction that is then converted to IOL power selection with proprietary formulas. However, obtaining accurate results with aberrometry requires careful attention to detail. In particular, it is essential to establish the intraocular pressure (IOP) at physiologic levels at the time of aberrometry to prevent errors in corneal curvature and axial length (AL). This requires a temporarily sealed incision.

Although some surgeons use wound stromal hydration to seal the cataract incision and fill the anterior chamber with a balanced salt solution before aberrometry, others fill the anterior chamber with an ophthalmic viscosurgical device (OVD) to avoid potential keratometric errors that might be induced by excessive hydration of the incision tissue. Little

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information is available regarding the effect of OVDs on the accuracy of aberrometry and IOL prediction power. In theory, results with OVD compared with a balanced salt solution might differ as a result of the variation in the index of refraction between individual OVDs and compared with balanced salt solution. The difference in the aphakic power of an eye with a balanced salt solution versus OVD in the anterior chamber is likely a result of the effect on the posterior surface power of the cornea (cornea/balanced salt solution versus cornea/OVD) because the anterior surface power (air/cornea) remains unchanged. The posterior surface power difference might be calculated using the indices of refraction for each OVD compared with a balanced salt solution.

The objective of the present study was to determine whether aberrometry readings for aphakic refraction and IOL prediction power differ when the anterior chamber is filled with balanced salt solution (BSS, Alcon Laboratories, Inc.) or various OVDs.

PATIENTS AND METHODS

A prospective interventional study was performed under the tenets of the Declaration of Helsinki with approval of the local ethics committee. The study was designed as an intrapatient controlled analysis. Patients presenting for routine cataract extraction were included. All cases were performed in a single setting (Specialty Surgery Center, Beverly Hills, California, USA) by 1 of 2 surgeons (S.M., N.F.) using topical and intracameral anesthesia.

Excluded from surgery were patients with previous refractive or corneal surgery of any type; ocular comorbidities that could affect aberrometry readings, including corneal surface disease, significant vitreous opacities, or elevated macular lesions; surgical complications; or a vision potential worse than 20/30. The study did not include surgically induced astigmatism (SIA) because only the spherical equivalent (SE) was considered and the surgical protocol was rigid with respect to incision size, instrumentation, and other factors.

The eyes were divided into equal groups. Each of the 6 groups was consecutively assigned a single OVD for investigation. The agents were Discovisc and Provisc (Alcon Laboratories, Inc.), Healon and Healon GV (Abbott Medical Optics, Inc.), and Amvisc and Amvisc Plus (Bausch & Lomb).

Preoperative testing included optical biometry. In an attempt to limit refractive variables, all eyes had a 2.2 mm temporal clear corneal incision and received a similar-platform single-piece acrylic IOL (Acrysof, Alcon Laboratories, Inc.).

At cataract surgery, after phacoemulsification, cortical removal, and posterior capsule polishing, the temporal corneal incision was carefully hydrated with BSS to create a watertight seal. Additional BSS was injected via a cannula into the anterior chamber to set the IOP at approximately 20 mm Hg as measured with a surgical applanation tonometer (Terry-Kratz, Ocular Instruments). By visual inspection, care was taken to avoid pressure on the globe from the lid speculum or sterile drapes. The surgeon manipulated the patient's head to center the cornea in the palpebral fissure, avoiding interference by the speculum.

Next, intraoperative aberrometry was performed with a biomechanical waveform analyzer (Ocular Response Analyzer, Wavetec Vision Systems, Inc.). The results of aphakic refraction and suggested IOL power were recorded; 3 readings were taken to ensure consistency and accuracy. Immediately after, the anterior chamber was filled with 1 of the 6 OVDs replacing the BSS, the IOP was set again with the tonometer, aberrometry was repeated, and the aphakic refraction and suggested IOL power were recorded. The IOL power suggested under BSS was used for IOL implantation in all cases. Cataract surgery was then completed routinely as follows: Anterior subcapsular lens epithelial cells were polished for 360 degrees, the single-piece acrylic IOL was inserted in the capsular bag, the OVD was fully aspirated, the IOP was set at the physiologic level, and the incision was hydrated and tested for watertight closure.

Manifest refractions were performed 2 to 3 weeks postoperatively, and the refractive spheroequivalent outcomes were analyzed to reflect the deviation from the desired refractive result (mean absolute error [MAE]). The difference in refractive accuracy between the aberrometry reading for BSS and OVD was the main outcome measure.

To reduce bias, a technician uninvolved in the study recorded the data intraoperatively. Another technician uninvolved and unaware of the study performed refractions, and the results were analyzed independently.

Statistical analysis was performed using SAS software (version 9.3, SAS Institute, Inc.). The differences between each group were evaluated using a nonparametric approach (Friedman chi-square test).

RESULTS

The study comprised 120 eyes, 20 in each OVD group. Table 1 shows the aggregate data for eyes with respect to AL (determined from preoperative biometry) and final IOL power. The range for both parameters was wide.

Aberrometry readings taken with BSS varied from those taken when the anterior chamber was filled with OVD (Table 2). In each example, the suggested IOL power was lower with OVD readings than with BSS. The results for Discovisc and Amvisc Plus

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From Advanced Vision Care (Masket, Fram) and the Jules Stein Eye Institute (Masket, Fram), David Geffen School of Medicine UCLA, Los Angeles, and the Specialty Surgery Center (Masket, Fram), Beverly Hills, California; Baylor College of Medicine (Holladay), Houston, Texas, USA.

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Corresponding author: Samuel Masket, MD, Suite 911, 2080 Century Park East, Los Angeles, California 90067, USA E-mail: avcmasket@aol.com.

Table 1. Conglomerate data for all 120 eyes in the study.

Parameter	Axial Length (mm)	IOL Power Implanted (D)
Mean ± SD	24.21 ± 1.39	19.52 ± 4.33
Median	23.94	20.5
Range	21.19, 29.82	+4.00, +30.00

IOL = intraocular lens

suggested an IOL power approximately 0.50 diopter (D) lower than readings taken with BSS, while the difference for the other agents was less than 0.25 D. In addition, the MAE outcomes were lower with BSS than with OVD, with the exception of Amvisc, for which the results were identical (Table 2). The differences were statistically significant with Discovisc ($P < .001$) and Amvisc Plus ($P < .026$).

DISCUSSION

The key finding in this study is that use of certain OVDs in lieu of a balanced salt solution at the time of aphakic refraction using intraoperative aberrometry might lead to an underestimation of appropriate IOL power. As the MAE outcomes show, the refractive outcomes measured with BSS anterior chamber fill were more accurate than when aberrometry was performed with OVD filling the anterior chamber. The MAE results for Discovisc and Amvisc Plus were clinically and statistically significantly different than those for BSS; IOL power selection with those agents would result in approximately 0.50 D of undercorrection. The most likely cause for this finding would seem to be the differences in the index of refraction between BSS and the individual OVDs. The agents with the greatest disparity in the index of refraction between BSS and OVD showed the greatest disparity in aphakic refraction and the suggested IOL power requirement. The optical effect can be explained by the fact that the physiologic negative posterior power of the cornea decreases as the index of refraction of the OVD increases above BSS. The net effect is an increase in corneal power above the BSS physiologic value, which in turn lowers the aphakic refraction of the eye, resulting in a lower recommended IOL power and thus undercorrection.

As seen in Figure 1, using the actual index of refraction for each OVD, the predicted aphakic power error in diopters is shown on the *y*-axis and the actual additional IOL power necessary is shown on the *x*-axis. The R^2 value of 90% between the actual and theoretical values is excellent. There are several explanations for

Table 2. Summary of outcomes data for all OVDs.

OVD	Intraocular Lens		Mean Absolute Error		*P* Value
	BSS	OVD	BSS	OVD	
Provisc	19.94	19.92	0.33 ± 0.31	0.37 ± 0.33	NS
Discovisc	19.64	19.02	0.47 ± 0.42	0.88 ± 0.49	<.001
Healon	19.54	19.43	0.40 ± 0.31	0.48 ± 0.32	NS
Healon GV	18.21	18.08	0.45 ± 0.36	0.53 ± 0.44	NS
Amvisc	19.33	19.30	0.31 ± 0.30	0.31 ± 0.31	NS
Amvisc Plus	19.68	19.20	0.29 ± 0.28	0.50 ± 0.36	<.026

NS = not significant; OVD = ophthalmic viscosurgical device

the remaining 10% of the data. Additional factors might be the variation in anterior chamber volume, a mix of OVD and BSS, a change in corneal shape that might be induced by the OVD, an OVD that is generally cooler than BSS, and aberrometry readings that are performed with white light rather than the monochromatic light that is used to measure the index of refraction.

Another possible explanation for the study findings is that the higher index of refraction of the OVDs could alter the wavefront estimation of AL, with agents having a greater index of refraction exhibiting a larger disparity from the readings under BSS.

As noted in Table 3, there are differences in chemical composition and rheology between the agents. Of the 6 tested agents, Discovisc alone contains a

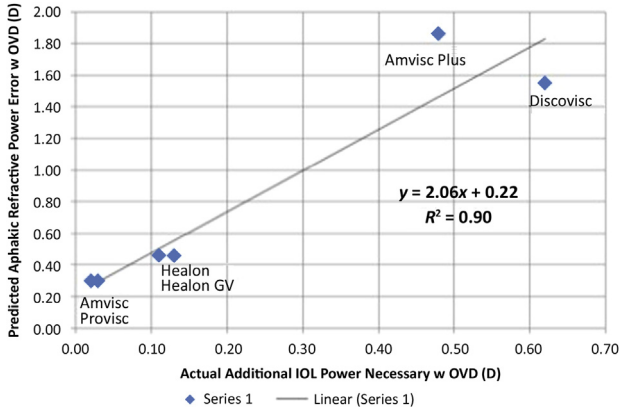

Figure 1. Predicted aphakic power error (based on index of refraction disparity between balanced salt solution and OVD) on *y*-axis versus actual aphakic power error (*x*-axis) as determined by manifest refraction. As noted (R^2), 90% of the observation might be attributed to the difference in the index of refraction, suggesting a strong correlation between aphakic power error and the index of refraction of the OVD (IOL = intraocular lens; OVD = ophthalmic viscosurgical device).

Table 3. Characteristics of OVDs.

Agent	Composition	Concentration (%)	MW (Daltons)	Index of Refraction @ 25°C at 546_u	Mean IOL Power Error Vs BSS
BSS	—	—	—	1.3340	
Provisc	HA	1.0	2.4 M	1.3380	0.02
Amvisc	HA	1.2	2.0 M	1.3380	0.03
Healon	HA	1.0	4.0 M	1.3370	0.11
Healon GV	HA	1.4	5.0 M	1.3390	0.13
Amvisc Plus*	HA	1.6	1.5 M	1.3480*	0.48*
Discovisc*	HA/CS	1.6/4.0	1.7 M/25.0 K	1.3460*	0.62*

BSS = balanced salt solution; CS = chondroitin sulfate; HA = hyaluronic acid; IOL = intraocular lens; MW = molecular weight
*Note the greater disparity of the index of refraction and IOL power between OVD and BSS with Amvisc Plus and Discovisc compared with the other agents.

mixture of sodium hyaluronate and chondroitin sulfate, whereas the other OVDs are purely hyaluronate based. There are differences in molecular weight and hyaluronate concentration as well.[4] Amvisc Plus and Discovisc have the same concentration of hyaluronic acid, perhaps explaining their similar optical behavior in the study. Although there are no previous studies of the influence of OVDs on intraoperative aberrometry, a recent one evaluated the focus shift effect of OVDs on the optical coherence tomography reading and treatment aspects of a femtosecond laser–created anterior capsulotomy.[5] In distinction from results in the present study, de Freitas et al.[5] did not find a clinically significant difference with OVD in their model. This might be because the 2 studies evaluated only 2 OVDs; that is, Healon and Provisc. Neither of those agents had a meaningful impact on aberrometry, nor did they affect femtosecond laser accuracy, likely a result of their relatively low index of refraction.

Nevertheless, the significant finding in our study is that 2 of the OVDs (Discovisc and Amvisc Plus) induced an error in intraoperative aberrometry that could result in an undercorrection of IOL power. However, the other tested OVDs did not result in significant differences from BSS. Therefore, surgeons might opt to use these agents to fill the anterior chamber before performing aberrometry readings. The chief advantage is that stromal hydration of the cataract incision is not necessary at this stage of surgery, thus avoiding the potential for altering corneal shape. In the future, adhesives might be used to seal the cataract incision temporarily in preparation for intraoperative aberrometry.

A potential weakness of the present study is the use of 2 surgeons in that they might have differed in technique, SIA, and other factors. However, the surgical protocol was rigid with respect to instrumentation, incision size, and placement. Moreover, only the SE was tabulated, reducing the significance of SIA. An additional concern might be the inclusion of eyes with differing ALs. However, as seen in Table 1, there was a large variation in AL and IOL power. Given that the study was designed with intrapatient control, the concern is lessened and the study results may be applied to eyes over a wide variation in AL.

As there are no previous similar studies, we look forward to corroborating or contradictory investigations. Moreover, because the current Ocular Response Analyzer device does not measure higher-order aberrations (HOAs), future studies might assess the influence of the presence of OVD on measured HOAs.

WHAT WAS KNOWN

- There is no information available regarding the influence of OVD on the accuracy of intraoperative aberrometry.

WHAT THIS PAPER ADDS

- There is evidence of an optical effect of varying OVDs on intraoperative aberrometry, providing a guide for use of certain agents.

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First author:
Samuel Masket, MD

Advanced Vision Care, Los Angeles, California, USA