SMILE: Improving optical quality
Exploring biomechanical advantages of preserving the anterior stroma

Microbypass trabecular stent efficacy
Stent reduces IOP and daily medication usage

Anti-VEGF treatment in DME
Positive effects observed in fellow eye following treatment

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Improved optical quality with SMILE

SMILE shows a lesser reduction in corneal tensile strength than LASIK and improves spherical aberration control

The introduction of small incision lenticule extraction (SMILE), a flapless form of keratomileusis, has changed the face of corneal refractive surgery in a number of ways, none more so than in corneal biomechanics and hence spherical aberration and optical quality.

In SMILE, the absence of a flap and the direct stromal lenticule extraction from within the body of the stroma through a 2-mm keyhole incision means that the anterior-most stromal lamellae remain intact postoperatively, except in the region of the small incision. This provides a biomechanical advantage as the anterior corneal stroma is known to be the strongest part of the stroma. For example, Randleman et al. measured the tensile strength of strips of stromal lamellae cut from different depths within the cornea and found a strong negative correlation between stromal depth and tensile strength. The anterior 40% of the central corneal stroma was the strongest region, whereas the posterior 60% of the stroma was weaker by at least 50%. Similar results for the nonlinear nature of stromal tensile strength have been reported by Scarcelli et al. using Brillouin microscopy.

In comparison, the anterior stromal lamellae are severed during laser in-situ keratomileusis (LASIK) by the creation of the flap and the excimer laser ablation, and by the excimer laser ablation during photorefractive keratectomy (PRK). Therefore, there is a lesser reduction in corneal tensile strength with SMILE than with LASIK and PRK.

Postoperative biomechanics

Surgeons are accustomed to calculating the residual stromal thickness in LASIK as the amount of stromal tissue left under the flap; therefore, the first instinct is to apply this rule to SMILE. However, the actual residual stromal thickness in this procedure should be calculated as the total uncut stroma (i.e., the stroma above and below the lenticule). Given the decreasing strength of stroma with depth, a more crucial factor than residual stromal thickness is tensile strength. In order to consider this, we have developed a postoperative total tensile strength (PTTS) calculator based on Randleman’s data. In an example treatment removing 100 µm of stroma via ablation (LASIK or PRK) or as a lenticule (SMILE) from a 550-µm-thick cornea, the model calculated the PTTS to be 75% after SMILE performed with a 130-µm cap, 68% for PRK and 54% for a thin-flap (100 µm) LASIK procedure.

We can take advantage of this postoperative biomechanical difference by better controlling the induction of spherical aberration to improve optical quality. To investigate this, we analysed the PTTS after myopic correction with SMILE and LASIK in cohorts of 96 eyes each, matched by sphere (±0.25 D), cylinder (±0.25 D) and pachymetry (±20 microns). Mean values for spherical equivalence (SEQ), cylinder and pachymetry in both groups were approximately –4.83 D, –0.56 D and 540 µm, respectively.

Improved optical quality with SMILE

In SMILE the anterior-most stromal lamellae remain intact postoperatively. Here, the author discusses the biomechanical advantages of preserving the stronger anterior stroma and the resulting effects on spherical aberration control and optical quality.

"...we can safely use SMILE to achieve an acceptable postoperative tensile strength.”
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The mean $\pm$ SD thickness of the cap in the SMILE group was 130 $\pm$ 6 μm and the LASIK group had a mean flap thickness of 96 $\pm$ 12 μm. Mean optical zone diameters were 6.7 $\pm$ 0.39 mm for SMILE and 6.08 $\pm$ 0.22 mm for LASIK. Mean lenticule thickness was 107 μm (range: 72–149 μm) for SMILE while the LASIK group had a mean ablation depth of 81 μm (range: 25–134 μm).

Mean PTTS was 73% (range: 65–82%) in the SMILE group and 57% (range: 45–72%) in the LASIK group. Across the entire range of myopia treated (up to –8.00 D), PTTS was about 16% greater on average in the SMILE eyes compared with the LASIK group.

**Spherical aberrations and PTTS**

Analyses of higher order aberration data found that SMILE induced significantly less spherical aberration than LASIK. Mean change from baseline spherical aberration was 0.11 ± 0.16 μm in the SMILE eyes and 0.31 ± 0.12 μm after LASIK ($p<0.01$).

Therefore, we found that spherical aberration could be controlled better in SMILE than in LASIK because we were able to increase the optical zone. Even though this meant greater tissue removal, the PTTS was still much higher in SMILE compared with LASIK. For example, in an eye with central pachymetry of 588 μm, a 7-mm zone was used to treat –10.00 D (203 μm tissue removal) with a 135-μm cap thickness. The stromal thickness under the lenticule was 250 μm, but the total uncut stromal thickness was 335 μm, which represents a postoperative tensile strength of 58%. In comparison, a –10.00 D LASIK treatment in which a 6-mm optical zone was used with a 100-μm flap left a residual stromal thickness of 298 μm, representing a postoperative tensile strength of 44%. The spherical aberration induced was 0.15 μm in the SMILE case and 0.75 μm in the LASIK case.

This example demonstrates how we can safely use SMILE to achieve an acceptable postoperative tensile strength. For an eye with pachymetry of 588 μm, we would be able to treat –16.00 D in a 7-mm zone, leaving 250 μm of total uncut stroma (but only 168 μm under the lenticule),
and a postoperative tensile strength of 44% — a level that has been considered safe in LASIK for two decades. The predicted spherical aberration induction for this correction would be only 0.39 μm, an improvement on the −10.00 D LASIK treatment.

Finally, there is the possibility of treating thinner corneas with SMILE. For example, the same −10.00 D correction in a 7-mm zone could be performed in a 490 μm cornea, leaving 236 μm total uncut stroma (154 μm under the lenticule) and retaining a postoperative tensile strength of 53%.

**Conclusion**
The superior tensile strength provided by preserving the stronger anterior stroma in SMILE allows larger optical zones, thus improving spherical aberration control and hence optical quality. This improvement is achieved while reducing the corneal tensile strength less than LASIK.

**REFERENCES**

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**Corvis® ST Highspeed Scheimpflug camera sets a milestone in ophthalmology**

Highspeed Scheimpflug camera in combination with non-contact tonometer:

- Precise measurement of the IOP
- Precise measurement of corneal thickness
- Information on biomechanical response
- Screening for ectasia
Photorefractive keratectomy has been an established method for laser vision correction for nearly 30 years. Its popularity amongst both patients and surgeons has reduced since the advent of laser-assisted in situ keratomileusis (LASIK).

However, there has been a renewed interest in surface ablation as a method for correcting refractive errors due to the advantages of maintaining corneal biomechanical strength and elimination of flap-related complications and optimization of the methods for epithelial removal.

The disadvantages of surface ablations have traditionally been postoperative pain, delayed epithelial healing and stromal haze. Modifications to PRK have been introduced to alleviate these issues. The key area that has been addressed in this respect is that of epithelial removal prior to excimer laser ablation. Ethanol has commonly been used as an alternative to mechanical debridement with preservation of the epithelial flap. An even more recent development is Transepithelial PRK (t-PRK) where epithelial removal is performed via laser phototherapeutic keratectomy (PTK) either through a two step or single step process.

Epithelial removal with surface ablation (two step vs single step)

t-PRK (2 step method)

Several studies have looked at the results of 2-step surgery using older generation broad beam laser systems in comparison to ethanol assisted PRK.

The results of two studies demonstrated better outcomes but in one there were overcorrections. In these studies the epithelium was ablated using a broad beam (even) PTK profile. A PTK treatment was initially performed to ablate the epithelium followed by a PRK procedure for correction of refractive error.

Transepithelial surface ablation (TESA) (1 step method)

The Schwind Amaris excimer laser (Schwind eye-tech-solutions, Kleinostheim, Germany) achieves epithelial and stromal ablation in a single uninterrupted step that consists of uniform precise epithelial removal followed by stromal ablation.

TESA differs from the earlier two-step methods by using a customized epithelial profile derived from population based high frequency digital ultrasonography. These studies demonstrated that the corneal epithelium is thicker in the periphery. This customized profile ablates 55 um centrally and 65 um peripherally for a typical 8 mm total ablation zone. There is a further compensation for differential ablation.

IN SHORT

- PRK has been an established method for laser vision correction for nearly 30 years, however, its popularity has reduced somewhat due to the advent of LASIK.
- With a recent renewed interest in surface ablation techniques some modifications have been made to alleviate disadvantages of the procedure. In this article, the authors highlight their clinical experience of TESA in myopic eyes with or without astigmatism.
between epithelium and stroma. Furthermore, TESA will also compensate for the phenomena of ‘epithelial masking’ in areas of stromal irregularity to achieve smoother ablations.

**Visual outcomes of single step t-PRK/TESA**

Fadlallah et al.\(^7\) found the visual outcomes comparable between single step t-PRK and a conventional alcohol-assisted PRK group. The postoperative mean sphere and mean astigmatism in the single step t-PRK group was \(-0.21 \pm 0.61\) and \(+0.43 \pm 0.62\) respectively. There was significantly less postoperative pain and rapid complete epithelial healing in the single step t-PRK group. Uncorrected distance visual acuity (UDVA) was not significantly different between the two groups at 3 months.

Postoperative corneal haze can also occur after PRK and their study found at postoperative 3 months, 10% of eyes in the single step t-PRK group had grade 1 haze compared to 26% in the alcohol-assisted PRK group.

Aslanides et al.\(^8\) found both single step t-PRK and the alcohol-assisted PRK groups to have safe outcomes. Their primary finding was that in the single step t-PRK group, patients had less early postoperative pain and photophobia on the third postoperative day with rapid epithelialization. Patients in this group also had better vision by 3 Snellen lines on this day. Corneal haze was significantly less at 1, 3 and 6 months (0.2 versus 0.43) but by year 1 there was no haze present in both groups. At postoperative 1-month, there was no significant difference in the unaided Snellen visual acuity (0.94 versus 0.97). Similarly, Fadlallah et al.\(^7\) also found no significant difference in visual acuity between the 2 groups at the 1 month and 3 month postoperative periods.

Luger et al.\(^9\) found that between the single step t-PRK group and an alcohol-assisted PRK, the postoperative mean spherical equivalent (SE) 1 year after surgery was \(+0.07\ D \pm 0.23\) and \(+0.01\ D \pm 0.27\) respectively and 97% of eyes in both groups achieved an UDVA of 0.1 logMAR or better.

**TESA: Our results**

We recently presented our unpublished clinical results at the 15th International Schwind Users Meeting 2014 in Vancouver, Canada,\(^9\) and at the XXXII Congress of the ESCRs 2014 in London, UK.\(^10\) In our retrospective analysis of patients treated in our Optimax Laser Eye Clinics in UK by five surgeons, 399 eyes underwent single-step laser epithelial removal and stromal ablation using the transepithelial PRK nomogram of the Amaris laser’s ORK-CAM software (Schwind eye-tech-solutions).

All eyes underwent ablation with an Aberration-Free algorithm.
optimizing refractive surgery

it was \(-0.17 \pm 0.18\) D (range: 0.88 to \(-1.25\) D). The manifest SE was within 0.50 D and 1.00 D of emmetropia in 89% and 99% of eyes, respectively (Figure 1). At 3 months, the preoperative manifest sphere was reduced from \(-3.58 \pm 1.44\) D (range: \(-0.50\) to \(-7.75\) D) to \(-0.05 \pm 0.33\) D (range: \(+1.25\) to \(-1.00\) D) and the preoperative manifest astigmatism was reduced from \(-0.60 \pm 0.53\) D (range: 0 to \(-3.50\) D) to \(-0.25 \pm 0.25\) D (range: 0 to \(-1.75\) D). UDVA of 20/25, 20/20 and 20/16 or better was achieved in 20%, 45% and 24% of 399 eyes, respectively (Figure 2). A gain of 1 or more lines was observed in 25% of eyes.

Postoperative corneal haze of \(\geq 1.5\) was observed in 2% of eyes only. Figures 4 and 5 display the visual outcomes of attempted versus achieved SE and stability of SE over time.

**TESA in summary**

TESA is effective at producing very safe and predictable visual outcomes for mild to moderate simple myopia or compound myopic astigmatism. We have also been able to demonstrate refractive stability and safety (clinically significant corneal haze is uncommon).

The role of the corneal epithelium as a smoothing agent in relation to any underlying stromal topographical irregularity allows transmission of the smoothness of the aspheric ablation profile to the underlying stroma. This yields more predictable refractive results and less induction of clinically significant corneal aberrations.

When t-PRK/TESA is used instead of ethanol assisted PRK there is the theoretical benefits of reduced postoperative dry eye, chronic ocular surface disease and recurrent corneal erosions. This is due to the reduced levels of keratocyte apoptosis.

with the Schwind Amaris at a repetition rate of 750 Hz pulse with 1050 Hz eye tracking. The laser ablation was centred on the pupillary axis. The intended refractive aim for all eyes was emmetropia and there were no retreatments included. Adjunct mitomycin C was not used in any patient.

The preoperative manifest SE was \(-3.88 \pm 1.47\) D (range: \(-1.25\) to \(-8.00\) D). At 1 month the postoperative manifest SE was reduced to \(-0.20 \pm 0.53\) D (range: \(-4.88\) to 1.88) and at 3 months...
The moment flapless surgery becomes clearly visible: in a smile.  
**This is the moment we work for.**

TESA represents an effective new method of surface ablation which is safe, predictable, stable and effective. Intraoperatively it is a very easy experience for a patient to undergo as it is painless, no touch technique (bladeless).

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Although effective at correcting simple spherocylinder refractive errors, conventional laser refractive surgery can have the undesirable effect of inducing spherical aberrations and reducing quality of vision. In conventional LASIK, laser pulses delivered to the periphery ablate less tissue than centrally delivered pulses because of their oblique angle of incidence on the corneal surface. This renders the cornea more oblate than prolate, thereby inducing more spherical aberration. Wavefront (WF)-based treatments attempt to compensate for this phenomenon with more sophisticated ablation patterns.1-5

Comparing WF-guided and WF-optimized treatments
WF-based treatments can be classified into two broad categories: WF-optimized and WF-guided algorithms. The WF-optimized approach considers an eye’s refractive error and preoperative keratometry, in conjunction with the variable ablation depths of peripherally delivered pulses, to apply a precalculated aspheric treatment that aims to limit induced spherical aberrations. The WF-guided approach renders a customized treatment plan based on an eye’s unique preoperative aberrometry with the intent of not only minimizing induced postoperative aberrations but also reducing or eliminating preoperative higher order aberrations (HOAs).

We conducted a prospective, randomized, eye-to-eye pilot study comparing WF-guided with WF-optimized treatments in hyperopes. The primary outcome measures included uncorrected distance visual acuity (UDVA), refractive stability, predictability, contrast sensitivity, HOAs, loss of corrected distance visual acuity (CDVA) and a validated quantitative questionnaire. There were no statistically significant differences between the groups for any of the variables studied after 12 months of follow-up (all P>0.05).

Both WF-guided and WF-optimized ablations were found to be safe, effective and predictable for the treatment of hyperopia with or without astigmatism. At 12 months, >90% of eyes in both groups had achieved ≥20/20 vision, and there were no statistically significant differences between the group’s mean CDVAs under <5% and <25% contrast sensitivity conditions (all P>0.05).

“We...WF-guided and WF-optimized LASIK performed on hyperopic patients, with or without astigmatism, can provide similar results...”

Study details
Eleven participants with hyperopia with or without astigmatism were randomized to receive either WF-guided LASIK with the VISX Star CustomVue S4 IR (Abbott Medical Optics, Santa Ana, California, USA) or WF-optimized LASIK with the WaveLight Allegretto Eye-Q 400 Hz (Alcon Inc., Hünenberg, Switzerland) in their dominant eye and the alternative in their other eye.

Patients underwent a comprehensive preoperative evaluation, including <5% and <25% contrast sensitivity (Precision Vision, La

IN SHORT
» In this article, the authors discuss how WF-guided and WF-optimized LASIK performed on hyperopic patients can provide similar results in terms of safety, contrast sensitivity and refractive error.
eye studies by Dr Manche.6–8 The employed in previous contralateral a questionnaire that has been evaluation, patients completed months 1, 3, 6 and 12. At each evaluated at postoperative cases. Patients were prospectively (Abbott Medical Optics, Cleveland, Ohio, USA) was performed in all pachymetry (Sonogage, Cleveland, Ohio, USA) and intraoperative ultrasonic flap depth setting was used, with a 105-μm programmed 9.2-mm-diameter superior hinge Ana, USA, California, USA). A (Abbott Medical Optics, Santa Center by a single surgeon Stanford University Eye Laser WF‑guided treatments. All surgeries were performed at Stanford University Eye Laser E.E.M.). LASIK flaps were created using the 150 kHz IntraLase iFS (E.E.M.). LASIK flaps were created using the WaveScan aberrometer (Abbott Medical Optics, Santa Ana, USA, California, USA). A 9.2-mm-diameter superior hinge with a 105-μm programmed flap depth setting was used, and intraoperative ultrasonic pachymetry (Sonogage, Cleveland, Ohio, USA) was performed in all cases. Patients were prospectively evaluated at postoperative months 1, 3, 6 and 12. At each evaluation, patients completed a questionnaire that has been employed in previous contralateral eye studies by Dr Manche.5–8 The questionnaire quantifies each of the following parameters on a grading scale of 0 (no symptoms) to 10 (severe symptoms): glare under night and day conditions, haze, halos, clarity under night and day conditions, dry eye symptom frequency and severity, foreign body sensation, vision fluctuation and ghosting. LASIK surgeries were performed in a bilateral simultaneous fashion to negate any learning curve with regard to the survey.

Results
Although the series is limited, with only 11 participants, to the best of our knowledge this is the first eye-to-eye comparison of WF-guided and WF-optimized LASIK for the primary treatment of hyperopia. In 22 eyes, WF-guided LASIK did not offer any statistically significant advantages over WF-optimized LASIK for the parameters studied at postoperative months 1, 3, 6 and 12, including UDVA, CDVA, contrast sensitivity, astigmatism, spherical equivalence, HOAs, efficacy, predictability and safety (all P>0.05). However, one must consider the alternative hypothesis that there was insufficient power to detect differences of potential clinical importance between the groups.

Previous studies of myopes have concluded that WF-guided approaches may yield small but statistically significant advantages compared with WF-optimized approaches. Our own study published in Ophthalmology found that WF-guided treatments performed with the WaveLight Allegretto demonstrated slightly superior predictability, better mean UDVA and less trefoil compared with WF-optimized treatments performed with the same machine.5 The absence of such differences after WF-guided and WF-optimized LASIK in hyperopes raises the question whether surgically induced HOAs are affected differently by WF algorithms in hyperopes compared with myopes.

Conclusion
Based on this small, prospective, comparative series of 22 eyes, we conclude that WF-guided and WF-optimized LASIK performed on hyperopic patients with or without astigmatism can provide similar results with respect to the parameters of safety, contrast sensitivity and refractive error. It is possible that WF-guided treatments offer some advantages over WF-optimized treatments, but this series lacked sufficient power to detect such differences if they were present. It will be of interest to see whether future studies with larger samples confirm our postulates, which should be interpreted with caution.

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Dr Manche holds equity in Calhoun Vision Inc., Kryton Vision Inc., Refresh Innovations Inc. and Seros Medical LLC, and works as a consultant for Oculeve Inc. and Best Doctors.
The clinical manifestations of seasonal allergic conjunctivitis (SAC) include ocular itching, ocular redness, chemosis, lid swelling, and tearing. Although these may not be serious, they can be very distressing to patients and have a negative impact on their daily activities, sleep, and quality of life.1–3

Opatanol solution (olopatadine hydrochloride 1 mg/mL; Alcon Laboratories) is a selective histamine-1 (H1) receptor antagonist and has been shown to stabilize human conjunctival mast cells in vitro and in vivo.4

Opatanol is indicated for treatment of the ocular signs and symptoms of SAC in patients 3 years of age and older.5 It is recommended to be administered as 1 drop twice daily for up to 4 months.5

Efficacy, safety, and comfort of Opatanol for treating SAC in children (≥3 years of age) and adults, and its advantages compared with other commonly used anti-allergy medications, have been demonstrated in randomized, controlled clinical trials.6,7 Findings from a few of these studies, which reflect the broad range of research conducted with Opatanol, are summarized herein.7–9

**Opatanol significantly reduced itching and redness compared with levocabastine 0.05% at 3 min and 10 min post challenge**

Results of a randomized, double-masked conjunctival allergen challenge (CAC) study demonstrated Opatanol was statistically significantly more effective than the H1 antihistamine levocabastine hydrochloride 0.05% ophthalmic suspension for reducing allergen-induced ocular itching and redness.7 The CAC is a validated method for evaluating the activity of topical medications for SAC.

The study included 68 adults with a history of SAC and a positive skin test for allergic disease. Patients served as their own control in this trial in which contralateral eyes were randomized to treatment with 2 drops of Opatanol or 2 drops of levocabastine 0.05%. At 27 minutes post treatment, patients were bilaterally exposed to a concentration of allergen previously proven to cause development of a threshold level of redness and itching. Analyses of evaluations performed at 3, 10, and 20 minutes post exposure showed that Opatanol was statistically significantly superior to levocabastine 0.05% in alleviating the intensity of the allergic response following the allergen exposure. Compared with levocabastine, eyes treated with Opatanol had significantly lower ocular itching scores at 3 and 10 minutes post allergen challenge ($P$≤0.001) (Figure 1) and significantly lower ocular redness scores at all 3 assessments ($P$≤0.0001) (Figure 2).7 Discomfort was the only ocular adverse event reported during the study, and it occurred much less frequently with Opatanol than with levocabastine (4.4% vs 26.5%, respectively; data not analyzed statistically).

**In an environmental study, patients found Opatanol more efficacious and comfortable compared with ketotifen 0.025% in treating ocular allergy signs and symptoms during the course of 4 weeks**

Investigators used an environmental model to assess patient preferences for Opatanol versus another antihistamine/mast cell stabilizer, ketotifen 0.025%.8 Conducted at 2 centers (Athens, Greece; Padova, Italy), the double-masked trial included 100 patients with a history of SAC or perennial allergic conjunctivitis who were experiencing current symptoms. In this real-world scenario study design, patients were given a masked bottle of each medication with instructions to use both as needed over the next 4 weeks, up to a maximum 2 drops of each medication per eye daily.
At study end, patients completed a 5-item questionnaire. Their responses showed Opatanol was consistently favored 4:1 over ketotifen with respect to being: the medication preferred to use more often (81% vs 17%); more effective for relieving allergy signs and symptoms (81% vs 19%); more comfortable (81% vs 18%); and the medication patients would request from their doctor during allergy season (81% vs 19%) (P<0.0001 for all comparisons). The decision for a future medication preference was based on both efficacy and comfort for 76% of patients (P<0.0001).

In post-hoc subgroup analyses of 2 studies, Opatanol was more effective than cromolyn 2% and levocabastine 0.05% in controlling ocular signs and symptoms in children at 6 weeks.

Researchers undertook post-hoc subgroup analyses of data from 2 randomized studies to characterize the efficacy and tolerability of Opatanol relative to cromolyn sodium 2% (Study A) and levocabastine 0.05% (Study B) for treating SAC in children. Participants in both trials had proven grass pollen allergies and were instructed to use their assigned study medication for 6 weeks during allergy season.

Self-rated ocular itching and investigator-rated conjunctival redness were assessed as the primary efficacy variables, and separate analyses were conducted to determine treatment responses during periods when pollen counts were at a peak level and when pollen counts were declining. During both the peak and declining pollen periods, children using Opatanol twice daily had significantly less intense itching than their counterparts using cromolyn sodium 4 times daily (P=0.010 and P=0.010) (Table 1). The results for ratings of redness intensity also favored Opatanol over cromolyn sodium during both the peak and declining pollen periods (P=0.003 and P=0.013) (Table 1). Compared with children using levocabastine twice daily, the Opatanol group had significantly less intense redness during the peak pollen period (P=0.040) (Table 1). Both ocular itching and ocular redness were less intense during the peak pollen period in children using Opatanol than in children using levocabastine (P=0.029 and P=0.032, respectively) (Table 1).

Conclusion
Allergic conjunctivitis is often a cause of patient visits to ophthalmologists. Although a variety of medications are available for its treatment, evidence from published papers should give practitioners confidence to choose Opatanol.

Clinical trial data demonstrate that Opatanol delivers relief for the spectrum of signs and symptoms associated with SAC with a convenient twice-daily dosing schedule. Furthermore, compelling data from a user preference study showed that when given the choice between Opatanol and another dual-acting antihistamine/mast cell stabilizer, patients with SAC expressed a statistically significant preference for Opatanol based on their perceptions of comfort and efficacy.

REFERENCES

Table 1. Mean scores for primary efficacy variables

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<th>Parameter/Study drug</th>
<th>Baseline</th>
<th>Peak</th>
<th>Declining</th>
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<tr>
<td><strong>Self-rated itching</strong></td>
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<tr>
<td>Opatanol</td>
<td>3.96</td>
<td>1.95</td>
<td>0.92†</td>
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<td>Cromolyn sodium</td>
<td>4.00</td>
<td>3.08‡</td>
<td>2.41‡</td>
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<td>Levocabastine</td>
<td>4.30</td>
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<td>1.00‡</td>
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<th><strong>Redness on slit-lamp examination</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Opatanol</td>
</tr>
<tr>
<td>Cromolyn sodium</td>
</tr>
<tr>
<td>Levocabastine</td>
</tr>
</tbody>
</table>

* Scale: 0 (none) to 4 (very frequently).
† P<0.05 versus baseline; ‡ P<0.05 versus olopatadine.
∞ = Scale: 0 (baseline, no dilatation of vessels) to 4.0 (beefy, tomato-red vessels).


OPATANOL® 1 mg/ml eye drops, solution (olopatadine). Prescribing Information. [Refer to full Summary of Product Characteristics (SmPC) before prescribing]. Presentation: 1 ml of solution contains 1 mg olopatadine (as hydrochloride); benzalkonium chloride 0.1 mg/ml. Indication(s): Treatment of ocular signs and symptoms of seasonal allergic conjunctivitis. dosage and method of administration: Adults, including the elderly: One drop in the affected eye(s) twice daily, for up to four months if necessary. Children and adolescents: (three years of age and older) same dose as adults. Hepatic and renal impairment: No dose adjustment expected. Contraindications: Hypersensitivity to olopatadine or any of the excipients. Warnings and precautions: OPATANOL, an antiallergic/antihistaminic agent, is absorbed systemically after topical administration. If signs of serious reactions or hypersensitivity occur, discontinue use. Benzalkonium chloride may cause punctate keratopathy and/or toxic ulcerative keratopathy. Close monitoring is required with frequent or prolonged use of OPATANOL in dry eye patients, or in conditions where the cornea is compromised. OPATANOL should not be administered while wearing contact lenses. Patients should be instructed to wait at least 15 minutes after instillation before inserting contact lenses. Interactions: No clinical interaction studies have been performed. Pregnancy and lactation: Olopatadine is not recommended during pregnancy and in women of child bearing potential not using contraception. Opatanol should not be used during breast feeding. Incompatibilities: In the absence of compatibility studies, this medicinal product must not be mixed with other medicinal products. Special Precautions for Storage: None. Legal Category: POM. Package Quantities and Basic NHS Costs: 5 ml £4.68. GMS Price: £7.44. MA Number(s): EU/1/2012/170/01-002. Further information available from the MA Holders: Alcon Laboratories (UK) Limited, Frimley Business Park, Frimley, Camberley, Surrey, GU16 7SR, United Kingdom. Date of preparation: December 2014 (V6). Adverse events should be reported. Reporting forms and information can be found at www.mhra.gov.uk/yellowcard. Adverse events should also be reported to Alcon. Tel: +44 (0) 371 376 1402. Email: GB.ADR@alcon.com.

A supplement to Ophthalmology Times Europe
Single-step transepithelial PRK as early treatment for LASIK flap buttonhole

Single-step transepithelial PRK treats flap buttonhole complications safely and effectively, with faster visual recuperation.

By Dr Shady T. Awwad

Buttonhole formation is a serious complication of laser in-situ keratomileusis (LASIK) that occurs in 0.2–0.56% of microkeratome-assisted LASIK, and sporadically with femtosecond laser-assisted LASIK, mainly due to aggressive dissection of tissue bridges on a thin flap.1–3 The conventional treatment has been to wait for 3 months for the buttonhole edges to completely heal then perform photorefractive keratectomy (PRK) with alcohol-assisted epithelial removal. Although it is very safe, this approach delays visual recovery, especially if the buttonhole occurred in the second operated eye, and allows for corneal haze and epithelial ingrowth development, two possible complications after flap buttonhole formation.

Single-step transepithelial PRK can be effectively and safely used to treat flap buttonhole complications within a few days to a week, allowing faster visual recuperation and better patient satisfaction.

Flap buttonhole management
Management of buttonhole complications is challenging. The immediate action is to abort excimer laser ablation and carefully replace the flap to maximize alignment between the flap buttonhole and the edges of the uncut tissue. Performing a deeper flap cut at a later stage can sometimes lead to slivers of loose stromal tissue.4 Performing an early PRK with alcohol or mechanically assisted epithelial removal is contraindicated for fear of displacing the buttonhole edges of the flap. Performing PRK with mitomycin C 2 months later, after waiting for complete healing of the buttonhole edges, might allow corneal haze, epithelial ingrowth and irregular astigmatism to develop, in addition to delaying visual rehabilitation, especially if the complication develops in the second eye.3

In contrast to chemical or mechanical epithelial debridement in PRK, transepithelial PRK avoids mechanical disturbance to the buttonhole edges as it is a no-touch laser technology and hence can be performed at a much earlier stage. Performing transepithelial PRK over the buttonhole LASIK flap several days after the complications, allowing for complete epithelial healing, has the advantages of bypassing the window period of haze and epithelial ingrowth formation and fast-tracking visual recuperation and rehabilitation without an undue waiting period.

Transepithelial PRK
The concept of transepithelial PRK was first described in 1999.5 Although it offers a simple and elegant way to remove the epithelium, transepithelial PRK never became the favourite PRK technique. Perhaps the single most important obstacle to transepithelial PRK is delayed healing of the buttonhole edges, which delays recovery and allows for corneal haze and epithelial ingrowth development. Here, early single-step transepithelial PRK is evaluated as an alternative.

IN SHORT

- Conventional buttonhole treatment involves a 3-month wait, followed by PRK with alcohol-assisted epithelial removal, which delays recovery and allows for corneal haze and epithelial ingrowth development. Here, early single-step transepithelial PRK is evaluated as an alternative.
PRK becoming a mainstream procedure was the fact that there was no systematic way to perform it. Using epithelial fluorescence to determine the stromal endpoint was deemed very subjective. In addition, the actual excimer treatment needed to be modified by +0.75 D to offset the hyperopic shift induced by the phototherapeutic keratectomy (PTK) mode. Finally, precious time was lost to re-planning and re-populating patient data between the PTK and PRK modes, potentially leading to stromal dehydration and interfering with treatment accuracy.

In contrast to chemical or mechanical epithelial debridement in PRK, transepithelial PRK avoids mechanical disturbance to the buttonhole edges as it is a no-touch laser technology and so can be performed at a much earlier stage. Performing transepithelial PRK over the buttonhole LASIK flap several days after the complication occurs has the advantages of bypassing the window period of haze and epithelial ingrowth formation, allowing for complete epithelial healing, and fast-tracking visual recuperation and rehabilitation, without an undue waiting period.

A new form of transepithelial PRK, known as single-step transepithelial PRK (TransPRK), combines defined-depth radial PTK treatment and PRK in a one-step procedure and was first implemented on the Schwind Amaris laser platform (Schwind Eye-Tech-Solutions GmbH, Kleinostheim, Germany). The laser fires the treatment profile first then switches seamlessly to a defined-depth radial PTK mode. In this mode, laser pulses are applied centrally to peripherally in a parabolic incremental fashion to mirror the published average profile of epithelial thickness, ablating 55 microns of tissue centrally and around 65 microns at the 8-mm zone, obviating the need for offset treatment correction. The software also compensates for the slight differences in photoablation rates of epithelial and stromal tissue.

**Single-step transepithelial PRK for buttonhole complications**

In our practice at the American University of Beirut Medical Center, we have used TransPRK to successfully treat LASIK flap buttonhole complications developing after either microkeratome or femtosecond laser. Development of a flap buttonhole complication, excimer treatment was aborted and the LASIK flap carefully repositioned. Patients were followed daily until the corneal epithelium had healed completely. The mean healing time was 5 days (range; 4–7 days). A new corneal tomography and an updated manifest refraction were performed, followed by single-step transepithelial PRK using the Schwind Amaris platform and the subsequent application of 0.02% mitomycin C for 45 seconds. Our published results on 8 eyes that were subsequently followed for 6 months, showed that the postoperative uncorrected distance visual acuity (UDVA) was 20/25 or better in 75% and 100% of patients at 2 and 4 weeks, respectively. UDVA was 20/20 or better in 88% and 100% of affected eyes at 4 weeks and 3 months postoperatively, respectively (Figure 1). Mean manifest refractive spherical equivalent and cylinder refraction were –4.00 ± 2.00 and –0.95 ± 0.55 D, respectively, preoperatively, and became –0.25 ± 0.42 and –0.56 ±
The fast improvement in visual acuity noted in the TransPRK eyes might be a result of the smaller epithelial defect created by the laser, which matches the stromal ablation both in centration and in the outer edge of the total optical zone. In addition, the epithelial wound edges are perfectly circular and healthy, resulting in swift epithelial recovery, in contrast to the ragged edges that result from mechanical ablation and the chemically treated contour of alcohol-assisted epithelial removal.

In irregular corneas, the epithelium acts as a masking agent and its surface is frequently less irregular than the stromal surface. One of the advantages of TransPRK is that the defined-depth radial PTK mode translates the epithelial surface down to the stroma, making topography-guided PRK more accurate because what is topographically measured is actually treated. Mechanical or alcohol-assisted PRK removes the very surface measured previously by topography, exposing a different, much more irregular, stromal surface.

We have shown using theoretical computer modelling that, in eyes in which the epithelium follows a parabolic profile and the central epithelium is thinner than 55 microns, single-step transepithelial PRK using a defined-depth radial PTK mode merely ablates more stroma. In the case of a thicker epithelial profile, the optical zone obtained is less than planned while the final target refraction remains unaffected. However, the main limiting factor is that the refractive effect of the epithelium, should it differ from the simplistic parabolic shape hypothesized by the procedure algorithm, is not accounted for. This might lead to occasional refractive surprises, which were shown to be neither clinically frequent nor significant in normal eyes, but which could be dramatic in some very irregular eyes.

Hence, there are recent methods that scan the epithelial layer then subtract it from the corneal surface to recover the actual stromal surface, upon which a customized topography-guided ablation is planned. Until now the process has been tedious and not systematic. However, it is only a matter of time before tomographs perform those steps automatically to provide the surgeon with a detailed map of the stromal surface upon the click of a button.

**Conclusion**

In conclusion, early single-step transepithelial PRK is a safe and effective way to treat LASIK flap buttonhole complications while minimizing waiting time and circumventing secondary complications such as haze and epithelial ingrowth.

**REFERENCES**


Following refractive surgery the absence of corneal subbasal nerve fibres (as a result of their removal during certain procedures) can cause multiple disorders, such as dry eye, hypeaesthesia and neurotophic epitheliopathy. These disorders can affect the patient anywhere from months to years post-surgery.

The nerve fibres do regenerate, however, the capacity of this regeneration can vary depending on the pre-op condition of the eye and the type of surgery employed. In our recent study, we sought to quality and quantitatively compare corneal subbasal nerve fibre regeneration variances after either small incision lenticule extraction (SMILE) or femtosecond laser assisted in situ keratomileusis (Femto-LASIK). Here, we present the details of this study and a brief overview of our findings.

Patients and procedures
We selected two groups of myopic patients of equal proportions — 20 patients (40 eyes) in the SMILE group and 20 patients (40 eyes) for the Femto-LASIK group — to investigate in this prospective cohort study. The age range of our study group was between 19 and 40 years old and all patients underwent standard pre-op evaluation.

The SMILE procedure was performed using a 500 kHz femtosecond laser only (VisuMax, Carl Zeiss Meditec, Jena, Germany). Femto-LASIK was performed using the same laser, with an intended flap thickness of 100 µm, and stromal ablation was performed using an excimer laser, MEL 90-500 Hz (Carl Zeiss Meditec). Two surgeons performed all the procedures. Our main outcome measure was corneal subbasal nerve regeneration, which we qualitatively and quantitatively measured using confocal microscopy (Confoscan 4, Nidek, Aichi, Japan) preoperatively and then 1, 3, 6 and 12 months postoperatively.

SMILE procedure
During the SMILE procedure we created two interfaces of lenticule in the corneal stroma. The lower interface was created initially (using an ‘out-to-in’ direction) with an average cup diameter of 7.72 mm ± 0.09 SD. After this a side cut incision was created at 90º and 15 µm in depth, which was then followed by the upper lenticule interface (using an ‘in-to-out’ direction). Finally, a 12 o’clock tunnel incision was made (3.60 mm ± 0.43 SD) to link the upper interface to the corneal surface. In our study, all patients had a lenticule predicted depth of 120 µm, an average lenticular thickness of 15 µm and an average diameter of 6.42 mm ± 0.15 SD for the optical zone.

After these interfaces were created, the patients were transferred to the surgical microscope for lenticule separation and extraction. This was done using a Seibel spatula for the anterior lenticule first and then...

In short
Following refractive surgery the absence of corneal subbasal nerve fibres can cause multiple disorders, such as dry eye, hypeaesthesia and neurotophic epitheliopathy. The nerve fibres do regenerate, however, the capacity of this regeneration can vary depending on the pre-op condition of the eye and the type of surgery employed. In a recent study, the authors sought to qualitatively and quantitatively compare corneal subbasal nerve fibre regeneration variances after either SMILE or Femto-LASIK. Here, they present the details of this study and a brief overview of our findings.
the lower lenticule interface was dissected in a similar fashion. When separation was completed we removed the lenticule from the cornea using a pair of retinal micro-forceps.

**Femto-LASIK procedure**

For this arm of the study population, we created a bladeless flap with the femto-laser. A series of bubbles were formed in a spiral pattern with a spot distance of 3–6 µm, which separated the stromal tissue and created the flap. We intended all flaps to have a diameter of 8.29 mm ±0.4 SD, thickness of 100 µm, a 90° hinge position with a 50° hinge angle and an average flap hinge width of 3.62 mm ±0.17 SD. We ablated the stromal bed using a MEL 90 excimer laser 500 Hz, with a Triple-A ablation profile.

**In vivo confocal microscopy**

All patients were examined preoperatively and at 1, 3, 6 and 12 months postoperatively using confocal microscopy. We fully explained the procedure to the patients and performed the analysis on both eyes. To avoid excessive blinking, we used one drop of Alcain as anaesthetic on the cornea. We used a drop of Viscotears on the lens, which served as an immersion and contact substance.

A fully automatic corneal scan was performed on each patient at a working distance of 1.98 mm, during which 350 images were obtained per eye. Our main area of interest was the corneal subbasal nerve plexus.

We evaluated all the images after the scan was complete and used the most qualitative subbasal nerve plexus picture for our further evaluation, which we performed with the help of

**Figure 1** Graphical demonstration of highly statistically significant results comparing Femto-LASIK and SMILE at pre-op and 12 month post-op periods: (a) nerve-fibre length changes; (b) nerve-fibre length density changes; (c) changes in number of beadings.
there was regression in all parameters, however, using the SMILE technique helped us to preserve subbasal nerve fibres better than with Femto-LASIK (Figure 2). Based on our results we concluded that less subbasal nerves were affected during the SMILE procedure and the nerve regeneration was faster than that observed after using the Femto-LASIK procedure.

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**Results and discussion**

The preoperative and 12-month postoperative characteristics for both groups can be seen in Table 1 and the results that were found to be highly statistically significant (p ≤ 0.001) can be found in Figure 1(a–c). We found that the highest differences occurred in the nerve fibre length, nerve fibre length density and the number of beadings. There was no statistically significant difference found between the NIDEK tortuosity parameter of the two groups.

When we analysed the in vivo confocal microscopy images over the 12 month follow up period, we clearly saw that specially designed software for nerve fibre assessment (Nidek nerve tracking tool).

In total, 80 frames were analysed from our 40 patients with an inspected field size of 460 µm x 345 µm. We calculated the nerve fibre length, nerve fibre density, number of beadings, beading density and Nidek nerve fibre tortuosity index for each frame and every parameter was measured at all time points pre- and post-op.
**TABLE 1: Preoperative and 12 month postoperative subbasal nerve-fibre parameter data in the Femto-LASIK and SMILE groups.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Femto-LASIK</th>
<th></th>
<th>SMILE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std deviation</td>
<td>Mean</td>
</tr>
<tr>
<td>Pre-op length (µm)</td>
<td>1130.85</td>
<td>422.42</td>
<td>1211.67413</td>
</tr>
<tr>
<td>12 month post-op</td>
<td>544.49</td>
<td>395.50</td>
<td>493.692523</td>
</tr>
<tr>
<td>Pre-op length density (µm/mm²)</td>
<td>13881.20</td>
<td>5311.39</td>
<td>14728.609090</td>
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<tr>
<td>12 month post-op</td>
<td>5756.84</td>
<td>4294.20</td>
<td>6001.155162</td>
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<tr>
<td>Pre-op number of beadings</td>
<td>87.89</td>
<td>39.66</td>
<td>89.54</td>
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<tr>
<td>12 month post-op</td>
<td>37.68</td>
<td>29.76</td>
<td>42.7917</td>
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<tr>
<td>Pre-op beading density (#/mm)</td>
<td>86.13</td>
<td>16.20</td>
<td>89.883771</td>
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<tr>
<td>12 month post-op</td>
<td>69.77</td>
<td>29.74</td>
<td>74.955800</td>
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<tr>
<td>Pre-op NIDEK tortuosity</td>
<td>9.42</td>
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<td>5.47365</td>
</tr>
<tr>
<td>12 month post-op</td>
<td>5.544625</td>
<td>2.7043614</td>
<td>5.325857</td>
</tr>
</tbody>
</table>

*References:
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The authors have no financial conflicts to disclose.
Does your choice of biometric device really matter?

Comparative results show devices should not automatically be considered equal

By Professor Jos Rozema

Nowadays a reliable biometry is the cornerstone of a modern anterior segment clinic. Consequently clinicians seeking to buy a biometric device are confronted with a wide range of possibilities and manufacturers that are heavily promoting their solutions. This situation can be daunting if the prospective buyer is not exactly sure about what they require and often leaves them with the question of which device is the ‘best’ or the ‘most reliable’.

Unfortunately, the answer to this question is not very straightforward as there is no universal reference objects available for comparison. This prompted my colleagues and I to turn to the next best thing, which is to use a cohort of human eyes as a base to analyse the agreement of biometric devices. However, while this has resulted in hundreds of peer-reviewed articles, one quickly notices that these often report very contradictory results.

Comparing devices

We were recently confronted with this issue during a multicentre study that included biometric measurements, when we noticed that many of the participating centres were using different devices and started to wonder whether this could influence the outcome of the study. Eventually this led to an article on the issues surrounding the comparison of biometric devices, containing a meta-analysis of the repeatability, reproducibility and agreement of various biometric devices based on a total of 216 articles that fit our search parameters.

Although there were far more relevant publications in the literature, we restricted our search to those using the Oculus Pentacam (Oculus, Wetzlar, Germany), Orbscan (Bausch & Lomb, Bridgewater, New Jersey, USA) and the IOLMaster (Carl Zeiss Meditec, Jena, Germany) as reference devices. These particular devices were chosen since these were found to be most often reported. We also restricted our search to those studies published after the year 2000, to avoid comparisons with older devices and outdated software.

We also aimed to make the comparisons as valid as possible by only considering papers where healthy eyes were used. This resulted in 70 comparisons, involving 24 devices and 9 biometric parameters.

Lack of equivalence

Of these 70 comparisons the average difference between devices was found to be significant in 17. Statistically significant differences, however, do not necessarily imply that devices are different in a clinical context.

For this reason, we subsequently performed a TOST analysis to demonstrate the equivalence of devices within certain clinically relevant thresholds based on the devices’ measurement error or the influence a certain error would have on IOL calculations. However, even with the most lenient thresholds we defined we could only demonstrate equivalence in about 50% of the comparisons, meaning that overall the biometry provided by different devices cannot be considered equal.

The source of this general lack of equivalence is most likely the large variation in the differences reported in the literature, which increases the inhomogeneity of the results. These variations may point at large calibration errors in some of the devices used and is a clear reminder that a device’s comparative results show devices should not automatically be considered equal

IN SHORT

> Nowadays, clinicians seeking to buy a biometric device are confronted with a wide range of possibilities, creating a daunting situation for the buyer. In light of this, Prof. Rozema and colleagues used a cohort of human eyes as a base to analyse the agreement of various biometric devices. In this article, the details of these analyses are revealed.
calibration should be verified regularly, both for clinical and for study applications.

Another factor that may have influenced the results is the large difference in the number of available papers for comparisons, with sometimes as many as 30 to 40 papers available for a single pachymetry comparison, and only one or two for many other parameters. This means that the inclusion of any of the new studies that are coming out every month could possibly alter the results.

**Silver lining**

Although devices may not be considered equivalent, there is a silver lining. For some parameters and some specific machines a strong and consistent equivalence was found. For example, this was the case for the Pentacam and Placido with regard to anterior keratometry, and the IOLMaster and the Haag-Streit Lenstar (Haag-Streit, Koeniz, Switzerland) for axial length, making it possible to compare ‘like-for-like’ in these few, rare cases.

Another positive outcome is the finding that overall biometric devices had similar repeatability and reproducibility values, meaning that the consistency of their measurements are likely to be similar as well. A few noted exceptions were the Galilei (Ziemer Ophthalmic Systems, Port, Switzerland), Sirius (CSO, Scandicci, Florence, Italy) and the RT-Vue (Optovue, Fremont, California, USA), which had markedly smaller measurement errors for pachymetry than the other devices.

**Cautious consideration**

These results suggest that from a clinical practice point of view individual patients should always be followed-up using one single device to prevent the influence of inter-device or calibration differences. Furthermore, the manufacturer’s recommendations to service the device regularly and to perform weekly calibration checks should be followed to the letter to avoid gradual changes in calibration over time.

For clinical studies, however, researchers should be cautious to consider the impact of equipment or calibration differences on the study outcome. This problem can be managed by either only including clinics using a particular ‘preferred’ machine, or simply ignoring the difference between machines. Both approaches have disadvantages though. The use of a single, preferred device for clinical research would set up an additional exclusion criterion that can seriously limit the number of centres participating. However, not only would this approach greatly reduce the number of potential participants, it would also fail to take any possible calibration differences between machines into account. This calibration issue is also present, albeit magnified, in the approach that simply ignores inter-device differences. In both cases there is a potential for introducing a systemic between-centre error into the study.

**Managing the errors**

Managing this error is not that difficult and can be done in multiple ways. In instances where only devices of a single type are used, one should verify the calibration of all participating devices prior to the study. Should a universal test object become available, this approach could be extended to studies using multiple devices as well. Alternatively, one could also include ‘device’ or ‘centre’ as a variable in the statistical processing to ascertain whether inter-device or calibration differences have an influence on the results. Should this not be the case, then investigators are free to ignore this factor.

So, while the different biometric devices should not automatically be considered equal, certainly not in the context of clinical research, there are a number of ways to deal with the issue. But given that the repeatability and reproducibility of the devices on the market overall are rather similar, your choice of device will probably not matter all that much, clinically.

**REFERENCE**


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Prof. Rozema has no financial interests relating to the subject matter of this article.

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Incorporating the effect of posterior corneal curvature in toric IOL calculations

Some adjustment is needed to achieve consistently excellent outcomes

By Felicity Thomas
Reviewed by Associate Professor Michael Goggin

From the earliest days of toric implants, surgeons worldwide have been delivering good outcomes for their astigmatic patients through good anterior corneal measurements and skilled surgery,” said Associate Professor Michael Goggin (University of Adelaide, The Queen Elizabeth Hospital and the South Australian Institute of Ophthalmology, Adelaide, Australia) during his presentation at the 2014 ESCRS Congress in London, UK. “To carry this to the next level and achieve excellent outcomes consistently, some adjustment for the posterior corneal astigmatism has to be made.”

Assoc. Prof. Goggin based this assessment on a recent study in which he evaluated whether the effect of posterior corneal astigmatism suggested by Koch and others was detectable in his practice.1 “I wanted to evaluate these suggestions before I started to make adjustments to account for any potential effect,” he added. “My plan was, if these suggestions were true I would introduce an adjustment for subsequent cases to allow for the effect in the absence of a reliable measure of the posterior corneal curvature and astigmatism.”

The study

The initial part of the study was to establish whether an average refractive over- or undercorrection of corneal astigmatism based on the ‘rule’ of astigmatism occurs if toric lenses are calculated based on anterior corneal measurements. Following on from this, the team looked at whether a systematic over- or undercorrection may occur throughout the dioptric range of toric IOL cylinders implanted. Finally, the team then calculated an adjustment that could be made for individual eyes to avoid this systematic error.

“Prior to the realization that the posterior corneal astigmatism was influencing the outcome for toric IOL implantation, the universal assumption was that the only significant source of refractive astigmatism in an aphakic eye was the anterior cornea,” explained Assoc. Prof. Goggin. “It was assumed that full correction for this could be delivered by toric IOL astigmatic power calculations based exclusively on anterior corneal data.

“Ideally, a device that measures both anterior corneal curvature and posterior corneal curvature accurately and repeatably, as well as good methods to calculate corneal powers from these data is required.”

Assoc. Prof. Goggin highlighted that the population tendency for the steep meridian of the posterior cornea should be aligned vertically. If using the anterior measurement alone in eyes with anterior WTR corneal curvature, an overestimation of the vertical meridian power will occur. Conversely, in eyes with anterior ATR corneal curvature the

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Assoc. Prof. Goggin discusses his recent study in which he evaluated the effect of posterior corneal astigmatism in toric IOL calculations and whether adjustments should be introduced to allow for such an effect.
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corneal astigmatism will be underestimated. “Toric IOLs chosen on the basis of these possibly erroneous estimates will leave remaining refractive astigmatic error,” Assoc. Prof. Goggin emphasized. “Some form of adjustment for the posterior corneal astigmatism is needed, perhaps not in all cases, but, by our data, at least in those requiring IOLs with 2 D of cylinder or less.”

Results
Based on the strength of the data previously presented by Koch et al., Assoc. Prof. Goggin noted that he was anticipating the posterior cornea to be a factor in toric IOL calculations. “However, we weren’t sure to what extent or what adjustment might be possible,” he said.

In the study group analysed, significant prediction errors of astigmatic outcome occurred in eyes with IOL cylinders of 2 D or less. “I was surprised that the apparent posterior corneal effect was only present in eyes receiving the lower IOL cylinder powers,” Assoc. Prof. Goggin continued. “The implication of this is that the relatively small contribution of the posterior corneal astigmatism may be swamped in eyes with larger anterior corneal astigmatism or that there is a true difference in posterior corneal shape between eyes with large corneal astigmatism and lower degrees of corneal astigmatism, which is something we are currently investigating.”

Conclusions
The results of this study demonstrated that augmentation of the toric correction of anteriorly measured ATR eyes and reduction for WTR eyes, especially for lower IOL cylinder powers, is necessary.

“Koch has suggested the Baylor Nomogram where an adjustment is made for all IOL cylinder powers up to 4 D. We suggest our Adelaide Nomogram where adjustment is made on the corneal astigmatism as measured anteriorly to allow for the likely effect of the posterior cornea prior to calculating the appropriate toric IOL power,” explained Assoc. Prof. Goggin. “We confine this to eyes requiring 2 D of IOL cylinder or less before adjustment, based on our findings. As we had relatively few eyes in our study with oblique anterior corneal astigmatism (steep between 31º and 59º or 121º and 149º) and in those that we had, we achieved accurate results without adjustment, we also exclude such eyes from adjustment.”

“We are also now routinely examining the posterior cornea qualitatively with a corneal tomograph, such as a Pentacam (Oculus, Wetzlar, Germany), in all eyes where we plan to make these changes to confirm the presence of a WTR posterior cornea,” he added. “This is the ideal and is useful for those surgeons with access to a tomographer.” For those surgeons without access to a tomographer, Assoc. Prof. Goggin stated that making these adjustments will still reduce the astigmatism in the postoperative populations. “Ideally, a device that measures both anterior corneal curvature and posterior corneal curvature accurately and repeatably, as well as good methods to calculate corneal powers from these data is required,” concluded Assoc. Prof. Goggin. “It would appear that a number of device developers and manufacturers have taken up this challenge but we await results.”

Acknowledgements
Assoc. Prof. Goggin would like to acknowledge the work of his fellow at the time of this research, Dr Lourens van Zyl, as well as the other doctors, nurses and technicians he worked with for the considerable extra time and effort they put in to make the measurements, adjustments and calculations for the patients and the help they provided in performing the research.

The study information presented in this article was published in full in the Journal of Refractive Surgery.

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Restoring accommodation

Pilot study data demonstrates efficacy of new lens

By Felicity Thomas
Reviewed by Professor Jorge Alió, MD, PhD

In a recent pilot study, led by Professor Jorge Alió (Vissum Corporation, Alicante, Spain), a new accommodating intraocular lens (IOL) — the AkkoLens Lumina (AkkoLens International, www.Akkolens.com) — was evaluated.

“I am the main clinical investigator of the AkkoLens Lumina and have dedicated a lot of time to the development with the company, and my coauthors, Alexander Angelov, Michiel Rombach, Aleksey Simonov, and Yavor Angelov,” confirmed Prof. Alió. “Over 70 patients have already undergone lens implantation in the pilot study, with extremely promising results.” In this article, Prof. Alió discusses the outcomes of this study.

An accommodating lens
The Lumina includes two aspheric varifocal optical surfaces, which, in combination, provide a lens of variable optical power when the surfaces move in a direction perpendicular to the optical axis (Figure 1), Prof. Alió explained. These two shifting optical elements can then achieve accommodation through the natural ciliary muscle movements of the eye.

“Significant improvement in near visual acuities were observed for the accommodating IOL while far vision is similar to that of a monofocal IOL.”

“The unique optical design is based on numerous surface corrections, including variable correction of a number of variable aberrations other than focus, which corrections are necessary to make the lens work,” he said. “The lens itself is implanted in the sulcus with the rim of the optical elements in contact with the ciliary muscle for optimum force transfer.”

The study
In the pilot study, Prof. Alió and colleagues implanted 72 eyes of 61 patients with IOLs — 22 eyes were implanted with a control lens (SA60AT, Alcon, Fort Worth, Texas, USA) and the other 50 patients with the AkkoLens Lumina (The Netherlands). Out of this study group, 26 patients were men and 25 were women. To objectively assess the accommodative ability of the lenses, the team used a wavefront analyser (WAM-5500, By Felicity Thomas
Reviewed by Professor Jorge Alió, MD, PhD

In this article, Prof. Alió discusses the outcomes of a recent pilot study examining the efficacy of a new accommodating lens.
Grand Seiko, Japan) and their subjective analysis of accommodation was examined by defocus curves.

**Results**
Concerning far vision, similar outcomes were found between the Lumina and the control lens when looking at the corrected distance visual acuities at all follow up points. However, statistically significant differences were observed between the groups when examining the **uncorrected near and distance corrected near visual acuities**. “Significantly better near visual acuities were observed for the accommodating IOL,” stressed Prof. Alió. (Figure 2)

Furthermore, no statistical difference was observed in the mesopic contrast sensitivity of the lenses for any spatial frequency cycle.

**Conclusions**
Based on the results of this pilot study, the team confirmed that the AkkoLens Lumina does **restore accommodation** and based on the subjective and objective data obtained, the accommodative range was found to be **between 1.5 and 6 D**. Almost all patients can lead a spectacle-free life.

**Further development**
According to Prof. Alió despite the initial surge in accommodating IOLs, most other accommodative IOLs have fallen by the wayside. “Right now, only the AkkoLens Lumina is providing true accommodation in combination with high visual acuities with very promising results,” he said.

In his opinion, accommodative IOLs that are situated in the capsular bag will always suffer from bag shrinkage and hardening. Also, the often needed YAG capsulotomies will destroy the integrity of the bag with serious and unpredictable consequences for any lenses in the bag. For accommodative lenses the sulcus is therefore the preferred position for an accommodative lens.1

“Regarding the AkkoLens Lumina, we have found that real accommodation is achievable, however, it now has to demonstrate its safety and stability in the long-term in the sulcus. For the Lumina, safety is now proven for over 5 years from the initial cases implanted during the feasibility study in Alicante, YAG capsulotomies have shown not to affect its performance, and continuing, active accommodation for more than 2 years has been shown in a large numbers of eyes,” he concluded.

**REFERENCE**
Anti-VEGF treatment and the fellow eye in DME: Is improvement possible?

Recent studies suggest it is, notes one ophthalmologist

By Dr Chrysanthos Symeonidis

During the past decade, anti-vascular endothelial growth factor (anti-VEGF) treatment has been employed for a wide array of retinal disorders: age-related macular degeneration, diabetic macular oedema (DME), retinal vein occlusions. The inclusion of several novel indications for anti-VEGF treatment is currently under investigation.

Despite the fact that the vitreal cavity is a relatively isolated milieu, there is definite communication with the systemic circulation. As anti-VEGF treatment became widespread (with bevacizumab being the first widely used anti-VEGF agent), the question of an effect in the systemic circulation as well as in the fellow eye arose.

Bevacizumab pharmacokinetics

Regarding bevacizumab pharmacokinetics in a rabbit model, a minimal quantity may be detected in the fellow eye following an intravitreal injection. According to Bakri et al.,\(^1\) maximum bevacizumab concentration was detected in the fellow eye 4 weeks following injection. This led to the conclusion that bevacizumab reached the anterior chamber through the anterior circulation and then entered the vitreal cavity by posterior diffusion. As bevacizumab half-life (in rabbit eyes) was established to be 4.32 days in the vitreous and 6.86 days in the blood serum, this slow systemic dissemination raises questions concerning the feasibility of a therapeutic effect in the fellow eye. In other words, that minimal quantity of bevacizumab may enter the fellow eye in time to bring about an effect.

A recent study paints a different picture: in rabbits, maximum bevacizumab concentration in the injected eye was detected within 6.61 days while maximum concentration in the fellow eye was detected within 8 days and followed by a relatively slow decline through week 4 after injection.\(^2\) This discrepancy in pharmacokinetics may explain the therapeutic effect (in the form of a decrease in central retinal thickness-CRT- in optical coherence tomography-OCT) in the fellow eye that was previously reported.\(^3\) Some authors report marginally non-significant CRT thickness but the number of eyes included was limited and injections were administered in 6-week intervals, possibly not allowing detection of subtle retinal changes.\(^4\)

DME morphology

DME morphology appears to be a significant factor in predicting the outcome of anti-VEGF treatment. In a small number of relevant studies, eyes were categorized as having cystoid macular oedema (CME) or diffuse macular oedema.\(^5\)–\(^7\) In the majority of these studies, intravitreal bevacizumab appears to have led to greater improvement on OCT in patients with CME compared to patients with diffuse macular oedema\(^5\)–\(^6\) while one study reports the opposite result.\(^7\)

It appears that pre-treatment morphology of the macula may contribute to the prognosis of treatment response. Other factors that may conceivably be regarded as potential predictors of response to DME treatment include lens status, age and visual acuity. According to

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- A positive anatomic and/or functional effect may be observed in the fellow eye following anti-VEGF treatment in the context of DME. Despite that this may be observed with bevacizumab, according to relevant experimental and clinical studies, a recent report suggests that this is possible with ranibizumab as well.
Karh et al., these factors were not found to be statistically significant while others such as glycosylated haemoglobin may be feasible parameters for future investigation.8

Ranibizumab pharmacokinetics
Regarding ranibizumab, pharmacokinetics appears to be significantly different. Compared to bevacizumab, ranibizumab is characterized by smaller molecular weight (149 kDa and 48 kDa, respectively). This may facilitate faster penetration of the retina as well as clearance to the systemic circulation.

Ranibizumab was not detected in the serum or the fellow uninjected eye in a rabbit model.9 Moreover, in a transgenic mouse model, no systemic effect was detected in contrast with significant suppression of neovascularization in the fellow eye that was observed following bevacizumab injection.10 Nevertheless, ranibizumab may be able to produce a systemic effect after all: peak ranibizumab concentrations have been detected as early as 3 hours following intravitreal 0.5 mg injection in both eyes in a monkey model.9 The penetration of a minimal quantity of ranibizumab in the fellow eye can not be ruled out as it may occur faster than anticipated and bring about an effect outside the standard timeframe of injection follow-up intervals (4 weeks).

Relevant literature
Literature on the effect of ranibizumab in the fellow eye in the context of DME is very limited. In a relevant study, patients were randomized to bevacizumab and ranibizumab treatment arms and followed-up at 2 and 4 weeks after injection.11 In the bevacizumab arm, there was a significant decrease in central foveal thickness (CFT) while no change was observed in the ranibizumab arm. This slight change did not translate into an improvement in best-corrected visual acuity (BCVA) in the bevacizumab arm. However, no significant improvement in BCVA or CFT was observed in the uninjected eye following ranibizumab injections.11

In a case reported by Rotsos et al.,12 a sustained positive effect was observed in the uninjected fellow eye following ranibizumab injections in the form of both anatomic and functional improvement. Despite the fact that only one eye was treated, OCT scans revealed bilateral DME elimination and considerable CME improvement. Fluorescein angiography (FA) revealed significant bilateral reduction of foveal leakage.

A possible explanation for these findings may lay with better patient compliance with physician recommendations regarding systemic diabetes care. It is conceivable that, in cases with marginal vascular damage, a modest improvement in dietary as well as treatment compliance may result (possibly temporarily) in an improvement in vascular status. This, in turn, may facilitate marginally improved anti-VEGF (in this case, ranibizumab) retinal penetration and may result in a measurable anatomic and/or functional improvement. These potential and therefore unpredictable changes may not be detectable with standard follow-up intervals.

To date, there are no clinical data available on a similar effect in the fellow eye following intravitreal aflibercept injection. As this particular anti-VEGF treatment becomes more commonly employed for this indication, it is conceivable that relevant publications will be available in the foreseeable future.

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Dr Symeonidis has no financial interests to disclose.
Microbypass trabecular stent delivers significant and durable efficacy

At 3 years, mean IOP reduced by 36% and a reduction was also seen in daily medication usage

By Cheryl Guttman Krader
Reviewed by Dr Tobias H. Neuhann

Implantation of a single microbypass trabecular stent (iStent, Glaukos, Laguna Hills, California, USA) — combined with small-incision cataract surgery — provides safe and sustained intraocular pressure (IOP) lowering, show data from follow-up through 3 years in a single-centre study, according to Dr Tobias H. Neuhann.

Dr Neuhann first began performing the microinvasive glaucoma surgery about 4 years ago, and has collected data from 62 eyes of 43 patients who underwent the combined procedure. Data from follow-up to 2 years were available for 45 eyes, and 41 eyes had reached the 3-year visit.

“At month 36, 79% of eyes had an IOP of 16 mmHg or less and 74% were medication free.”

At 3 years, mean IOP was reduced by 36% from its preoperative medicated level. Dr Neuhann, Medical Director at AaM Augenklinik am Marienplatz in Munich, Germany, reported that the observed improvement was achieved with an 84% reduction in daily medication use and an excellent safety profile.

Durable and efficient

“Patients with glaucoma who undergo cataract surgery typically achieve some IOP-lowering benefit, but it usually only persists for 6 to 12 months,” he said. “Therefore, the magnitude and durability of the efficacy of this combined MIGS- cataract surgery is remarkable, and importantly, its benefit was achieved without any intraoperative complications or any of the more serious complications that occur with filtration surgery.”

“Best-corrected visual acuity (BCVA) was 20/40 or better in 44% of eyes preoperatively and in 93% of eyes at month 36.”

The study cohort included 39 eyes with primary open-angle glaucoma, 11 eyes with pseudoexfoliation, 10 eyes with ocular hypertension, and 2 eyes with secondary glaucoma. Sixty percent of the eyes were surgically naïve, but 13% had prior trabeculectomy and others had undergone some laser procedure. Most of the eyes were being treated with 2 topical medications and 18 were using 3 or more medications. Mean IOP was 24.1 mmHg preoperatively on medication, was reduced to 14.2 mmHg at 3 months and remained stable throughout follow-up, averaging 14.5 mmHg at 24 months and 14.9 mmHg at 36 months.

“We did not separate the eyes by diagnosis, but we observed it did take a little bit longer for the IOP to fall after surgery in the pseudoexfoliation cases compared with the open-angle glaucoma patients,” Dr Neuhann said.

Average medication use was reduced from 1.8 preoperatively to 0.3 at month 6, 0.2 at month 24, and 0.3 at month 36.

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A 3-year follow-up of eyes undergoing combination cataract surgery with implantation of a single microbypass trabecular stent shows a 36% reduction from baseline mean medicated IOP and an 84% reduction in daily medication use.
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“At month 36, 79% of eyes had an IOP of 16 mmHg or less and 74% were medication free,” Dr Neuhann said. “The results at 36 months are similar looking and consistently observed in the cohort of 39 eyes.”

Best-corrected visual acuity (BCVA) was 20/40 or better in 44% of eyes preoperatively and in 93% of eyes at month 36. “The BCVA was excellent as we expect when we do cataract surgery,” Dr Neuhann said.

During follow-up, two patients became intolerant to topical and systemic IOP-lowering therapy and underwent shunt surgery. One eye had photocoagulation. The stent was placed into Schlemm’s canal through the same temporal, limbal incision used for the cataract procedure and after filling the anterior chamber with viscoelastic.

**Surgical pointers**

To facilitate visualization, Dr Neuhann suggested performing the insertion from the temporal side with the help of a gonioscopic lens, tilting the microscope towards the surgeon and the patient’s head away. To guide accurate placement of the stent, Dr Neuhann explained that he massages the collector channels and veins until the channels fill with blood. “When you see the blood, you know you are where you want to go,” he said.

Eyes may rarely develop hyphaema postoperatively from bleeding through the channels, but in the absence of that event, postoperative bleeding is a positive sign. Dr Neuhann added, “Blood is the enemy of glaucoma surgery, but in this case, it is your friend because it shows the stent is in the right position.”

“Blood is the enemy of glaucoma surgery, but in this case, it is your friend...”

**Dr Tobias H. Neuhann**

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Dr Neuhann has no relevant financial interest to disclose.
NEW ICARE HOME SELF-TONOMETER FOR EASY 24H IOP MONITORING BY OPHTHALMOLOGIST RECOMMENDATION
Combatting the ‘plague’ of diabetes

Dr Raju reveals his opinions on the current state of affairs and how education is key

By Paul Myles
Reviewed by Dr V.K. Raju

The prospect of mass blindness, even in the populations of developed Western nations, could become a reality unless measures are taken to combat the latter-day ‘plague’ of diabetes.

That’s the opinion of the world-renowned ophthalmologist Dr V.K. Raju who recently accepted the Mahatma Gandhi Pravasi Samman Award during a presentation in the House of Lords in London, UK, recognizing his lifelong achievements in the field.

Yet, despite the work to identify those most at risk from avoidable blindness by the Eye Foundation of America, which he founded in 1979 and is its medical director, Dr Raju has warned that not nearly enough is being done to stave off an avalanche of diabetes related blindness that is gathering in strength.

Speaking exclusively to Ophthalmology Times Europe, Dr Raju said, “Diabetes really has the ability to wipe us out. One of my mentors Dr Rollin Arthur Burn in London told me there are three solutions to any problem: first is education, second is education and third is education.

“If you look back even to the Great Plague it was defeated by prevention, polio has almost been eradicated by prevention and diabetes is no different.”

Improving visual health

His own foundation’s activities has improved the visual health of more than 1.9 million people in 21 countries and includes major screening programmes in both India and the US.

Dr Raju helped found two eye institutes in Andhra Pradesh, India — the Srikiran Eye Institute in 1993, which is now independent and self-sustaining, and the Goutami Eye Institute in 2005, a modern-equipped eye hospital in Rajahmundry, India, with a wing dedicated to children’s eye care. The institute has become a global training centre for education and exchange programmes and has trained teachers to screen 200 000 school children for symptoms of early eye disease.

Last year the Eye Foundation of America launched its ‘100000 Lives’ campaign using a specially developed mobile unit to screen rural Indian communities for diabetic retinopathy, a stalking horse condition that causes blindness in sufferers of high blood sugar levels.

“Diabetes really has the ability to wipe us out.”

Dr Raju explained, “There are three conditions eyes are prone to with diabetes. First, is leaky blood vessels at the back of the eye and it can take between 6–7 years for this to manifest itself (diabetic macular oedema — DME). So, if we can reach the patients early we can prevent the onset of blindness. If the prevention of diabetes programme and early intervention are done meticulously only 10% of diabetics have disabling visual problems, so the key is early treatment to control blood pressure and blood sugar levels and cholesterol. Early intervention and education can reduce these problems. In other words, how do we change the lifestyle of a patient. Today many patients know about healthy choices but they do not make them.

“Secondly, early cataracts are much more common in diabetics than non-diabetics. It is said the world over that while today the cataract problem is the biggest issue, the diabetic problem will be 10–15 times worse than cataracts. We are talking about millions of people who could be

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» With the rise of diabetic cases occurring the world over, measures are urgently needed to combat this disease, according to Dr Raju. Here, he discusses the problem, his foundation’s activities to help improve visual health and how education is key to staving off the threat of widespread diabetes.
“It is just impossible to keep on performing tertiary care with diabetes.”

Thirdly, glaucoma is two to three times more common in diabetics. This is high pressure in the eye that can cause blindness because when it goes over the 22 mmHg it can slowly damage the eye. Again, if we catch them early there is an incredible range of medications and even surgery that can save the sight today and these were not available 30 years ago when I was working in England.”

Tertiary care cannot continue
Dr Raju stated the treatment for diabetic retinopathy begins by simply monitoring the sufferer’s condition. “However, if we think it is getting worse and the patient experiences minor symptoms, we can either treat it with lasers or, even more importantly, using an anti-VEGF injection, specifically bevacizumab (Avastin, Roche, Basel, Switzerland),” he explained.

“Although there are three or four alternative drugs available, for me bevacizumab is the most practical because of the cost. In the US, it costs about $50–$60 per injection and, usually, three injections are used as a minimum and once stabilized, a follow on may be required in the future, if they...
follow the doctor’s advice about weight, blood sugar, cholesterol and moderate exercise, you can expect the patient to have a pretty good chance of staying in remission.”

However, Dr Raju admits efforts at tertiary care are like pushing a finger into a bursting dyke holding back a flood of healthcare problems facing both developed and under developed countries alike.

He said, “It is just impossible to keep on performing tertiary care with diabetes. In the US, for example, last year the country spent close to $3 trillion on healthcare — that’s the entire economy (GDP) of France.1,2

“Wilfred G. Oakley, a diabetologist in 1962 said, ‘man maybe caption of fate but is also a victim of his blood sugar’. I quoted this while presenting at the 5th meeting of the Global Physicians of Indian Origin (GAPIO), which is 1.2 million doctors strong. The next one will be in Leicester, UK, in the last week of June. If we can get all these professionals to work together on this — the sky is the limit. However, we still have to concentrate on preventative measures rather than the tertiary treatments for eye problems, heart problems, kidney problems and so on. Treating these will not solve the cause.”

An old warning
Dr Raju bemoans that experts have been warning the world of this problem for years and yet comparatively little is being done to address the root causes of diabetes.

“There have been several excellent papers in the late 1990s and early 2000s on this issue and the authors have warned about the growth of this problem,” he continued. “Yet, 15 years later, nothing has got any better. So, if the trend continues at the present rate of growth the US alone will have, in the next 15-20 years, around 100 million diabetics. Today we have about 20 million diabetics and the others are all pre-diabetic.”

“If he [the primary care practitioner] has enough time and educates the patient, a lot of tests and procedures can be avoided... We need EDUCATION, EDUCATION AND EDUCATION and policy makers need to be educated too.”

His own personal experiences as a young eye doctor working in London during the 1970s helped drive his passion for reversing the trend on increasing numbers of people suffering avoidable blindness.

He tells a story of one British farmer who only sought help after losing sight in one eye. Raju said, “A patient would come with bleeding in the eye because he had lost vision and had never had regular examinations. I remember he was a farmer and a pretty healthy guy. When he came to the Royal Eye Hospital I asked him, ‘do you have diabetes?’ He replied, ‘No, no sir’. Yet his blood results showed a very high blood sugar. It was that simple for a doctor to look into a patient’s eye to detect diabetes.

“But, naturally, it would be too late by then because it means that diabetes has been there seven years or so and, in this case, the damage was already done.”

At the time, his mentor Dr Burn, also imparted another piece of advice that Raju believes should not be ignored by all on the medical profession. “Dr Burn would tell me that doctor in Latin means teacher and ‘Raj we must teach people’. Today this has become so difficult with the pressures on doctors such as internists, diabetologist and the family practitioners need more time to sit with the patient,” he said.

EDUCATION is key!
Raju insists that for doctors to have a real impact on combatting the threat of widespread diabetes with all its ensuing health risks and costs to society, the role of the primary care practitioner must be to lead the team of medical professionals.

“If he has enough time and educates the patient, a lot of tests and procedures can be avoided,” Dr Raju continued. “Otherwise, when the patient goes to the family practitioner, who does not have the time, the patient gets referred to the endocrinologist, the ophthalmologist, kidney doctor, cardiologist, neurologist, foot doctor and finally the psychiatrist.

“And here, the media, too, has a great role to play, more than ever. We need EDUCATION, EDUCATION AND EDUCATION and policy makers need to be educated too.”

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Dr Raju has no other financial disclosures relating to the content of this article.

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Imaging & Diagnostics

3 AngioVue in clinical management of type II choroidal neovascularization in AMD before and after anti-VEGF treatment

OCT angiography has brought impressive changes and improvement to the retina practice of Drs Lumbroso and Rispoli since they introduced it last year. Here, they present an example of this imaging technique in the clinical management of type II choroidal neovascularization in AMD before and after anti-VEGF treatment.

IOLs and biometry

4 First clinical experience and results with a novel IOL system for dry AMD

A novel IOL system offers significant surgical and optical advantages compared with previous technology, and its features make it an exciting advance for cataract surgery patients with vision loss related to macular disease. In this article, first clinical experience and results with this technology for dry AMD patients.

5 The new IOLMaster 700 from ZEISS — First Results concerning the Cataract Penetration Rate

In a recent study, Dr Puech and colleagues evaluated a new biometric device, the IOLMaster 700 — which now incorporates SWEPT Source OCT technology, with the prior model to discover in how many cases limited transparency of ocular media made biometric measurements impossible.

Laser Surgery

6 SMILE — from initial experiences towards the future

According to Professor Alió, femtosecond assisted intrastromal lenticule extraction could be defined as the ‘refractive surgery of the corneal surgeon’. Here, he discusses his experiences and what the future holds for the technique.

Perimetry

7 Humphrey Field Analyzer 3 from ZEISS: Improving on a Standard

Since its introduction over 30 years ago, the Humphrey Field Analyzer has become the standard method to assess and monitor visual field loss. To prepare for the launch of the new HFA3, ZEISS performed a survey in 19 evaluation sites to determine the early impressions of this new platform. A summary of the survey results is presented in this article.

9 Product Profiles
AngioVue in clinical management of type II choroidal neovascularization in AMD before and after anti-VEGF treatment

By Dr Bruno Lumbroso and Dr Marco Rispoli, Rome, Italy

OCT angiography has brought impressive changes and improvement to our retina practice since February last year when we began to use OCT angiography. It complements the information given by fluorescein angiography (FA) and brings new elements to FA. Sometimes it can replace it.

Instrumentation/equipment used
AngioVue (Optovue, Fremont, California, USA) is dramatically modifying the way retina specialists use imaging.

Methods
FA uses a dye injection to highlight the vascular network, but it could lead to side effects, whereas AngioVue records the movement of blood cells inside the vessels. FA needs to be scheduled, but OCT angiography can be performed at any time in the office.

Images/figures/tables
We are showing a series of Angioflow images from AngioVue from one eye with CNV type 2 in AMD, treated with intravitreal aflibercept.

Figure 1 was taken before treatment. It showed a neovascular network with many tree-like anastomoses. We often found in our images an afferent vessel and peripheral anastomoses. In age-related macular degeneration, choroidal neovascularization is typically seen as a sharp vascular net, one that is not blurred by dry leakage.

Figure 2 was taken 24 hours after aflibercept injection. It was obvious that the neovascular network was much smaller, with fewer anastomoses. Flow changes produced a fragmented aspect of the network. Secondary branches decreased or disappeared entirely post-injection. The presumption was that flow decreased inside the capillaries but what surprised us was that these same branches re-appeared later in a few weeks’ time.

Figure 3 showed that by day 35, the neovascular network was back almost to baseline level. The only difference was that some branches appeared to be thicker. In my opinion, this was confirmation that this patient could be on monthly treatment regimens.

Results
AngioVue images differ from fluorescein angiography images. They do not show dye leakage or staining. They provide an important additional diagnostic device to our technology.

OCT angiography shows the vessel contents and does not show their walls. That allows us to highlight capillary abnormalities much better than we could with FA.

Conclusion
This new technology provides clinicians with new useful information that is less expensive to administer than current imaging modalities and that has fewer side effects. In short, Angioflow images on AngioVue may be the future of retinal imaging. There is, however, a learning curve when you begin to use this Non-Invasive Microvascular Imaging technology.

Full details of the AngioVue can be found on page 9

www.oteurope.com
IOLs and biometry

First clinical experience and results with a novel IOL system for dry AMD

By Dr Fritz Hengerer, PhD, assistant professor of ophthalmology, Goethe-University Frankfurt am Main, Frankfurt, Germany. A new intraocular mini-telescope (iolAMD, London Eye Hospital Pharma) offers significant surgical and optical advantages compared with previous technology, and its features make it an exciting advance for cataract surgery patients with vision loss related to macular disease. Here, I will present the reported outcomes achieved after 4 months of follow-up in 18 eyes implanted by Dr Bobby Qureshi along with my own initial clinical experience with the intraocular mini-telescope.

Dr Quereshi’s series
For the eyes in Dr Qureshi’s series, mean Snellen preoperative near uncorrected visual acuity (UCVA) (decimal) was worse than 0.14, preoperative distance best-corrected visual acuity (BCVA) was 0.12, and simulated distance BCVA was 0.19. Mean postoperative distance BCVA was 0.2, exceeding the simulation-predicted value, and mean near BCVA improved by 50% to 0.21.

The refractive outcomes were similar to those achieved with monofocal implants. There was a myopic shift in all cases from pre- to postoperative (mean 1.5 D) and a mean of about 0.5 D of induced astigmatism. However, the refractive changes can be neglected.

There were no intraoperative or postoperative complications. Mean IOP was 18 mmHg preoperatively and 16 mmHg postoperatively, and mean endothelial cell count showed a decrease of about 18%.

Images from anterior segment OCT demonstrated stable lens positioning and microperimetry results confirmed the benefit of the telescopic and prismatic effect for improving threshold sensitivity and fixation stability.

First implantation
I performed my first implantation of the device in July 2014 in a patient with stage 3 AMD who had a monofocal IOL in the fellow eye. My next two cases were in the fellow eyes of a second patient with stage 3 AMD. All of the procedures were done through a 3.2-mm superior incision with a 5-mm capsulorhexis.

In the first implanted eye, baseline distance BCVA was 0.03. The patient was unable to read with that eye, but the simulation predicted near BCVA would improve to 0.1 after implantation of the intraocular mini-telescope. At 30 days postoperatively, near and distance UCVA were both 0.25, distance BCVA was 0.4 and near BCVA was 0.5.

With these outcomes, the patient had visual acuity that allowed him to keep his driver’s licence.

The results from the second patient who received the intraocular mini-telescope in both eyes suggested outcomes are enhanced with binocular summation.

Preoperatively, distance BCVA was 0.05 in the left eye and 0.16 in the right eye. The patient was unable to read with his right eye and had 0.16 BCVA at near in the left eye.

In binocular testing at 30 days after the second eye surgery, distance UCVA was 0.5, near UCVA was 0.63, and BCVA for both near and distance was 0.8.

The patient is very happy and particularly pleased because he is able to read stories to his grandchildren, which he could not do before.

I would also emphasize the importance of completely removing viscoelastic between the two lenses to optimize their relative positioning, and I must note that there is the potential to adjust the orientation of the sulcus lens in a future procedure to improve vision for patients when their macular pathology advances.

The sulcus IOL is not fixed like a toric lens, but can be rotated later according to the patient’s needs, potentially extending vision as the disease progresses.

More information about this product can be found on page 9
For more than 15 years, the IOLMaster has become the benchmark for optical biometry instruments\(^1\) with a large number of devices in use and excellent compatibility with the values of the IOL constants given by the ULIB site. The arrival of a new biometric instrument, the IOLMaster 700, has generated great interest. This is particularly the case because it is the first time that SWEPT Source OCT technology has been brought into the field of biometry. This technology provides clear advantages over the previous systems, including the possibility of detecting unusual eye geometries and poor fixation patterns. This allows for a more accurate performance of IOL power calculations and, consequently, a significant improvement in the refractive outcomes. Furthermore, the SWEPT Source OCT technology has the additional advantage of its extremely rapid data acquisition,\(^2\) including the ability to measure the axial length along 6 different axes.

We have recently performed a study comparing the new IOLMaster 700 with the previous IOLMaster 500. We sought to discover in how many cases limited transparency of ocular media made biometric measurements impossible.

**Methods and materials**

Patients who were referred to the Centre Explore Vision in Paris for IOL power calculation were consecutively included in this prospective study. In all cases, axial length measurements were performed with the IOLMaster 500, followed by a measurement with the IOLMaster 700. A total of 427 eyes were examined, of which 288 eyes were eligible for the current study. The exclusion criteria included eyes with active ocular pathologies, such as uveitis or retinal degenerations, as well as eyes that had undergone previous ocular surgery. We counted the cases where no measurement was possible, which was most frequently due to the loss of transparency in the media, and then compared this number between the devices.

**Results**

It was not possible to obtain a biometric measurement in a total of 31 eyes (10.76%) with the IOLMaster 500. In all cases, this was due to the reduced transparency in the ocular media of these eyes. In contrast, with the IOLMaster 700, it was only in 16 eyes (5.55%) that no measurement was possible. This was also due to the insufficient transparency of the ocular media. In our sample, the IOLMaster 700 halved the number of cases in which an axial length measurement could not be obtained.

**Discussion**

The fact that the IOLMaster 700 performs 6 radial scans helps to optimize the axial length measurement when compiling the results. This seems to be the main reason to explain our results. Likewise, the fact that SWEPT Source OCT technology is used, has the advantage that the entire eyeball is scanned, and the different structures to be found in the entire visual axis are recognized. This facilitates the proper axial length measurement, even in the presence of some dense cataracts. Furthermore, unusual eye geometries such as tilt or decentration of the crystalline lens can be detected and taken into consideration in the choice of IOL model. The fixation check of the IOLMaster 700 is another advantage of this new biometer. It enables the examiner to check whether the image is being obtained in the right position and to reduce the risk of refractive surprises due to incorrect measurements caused by undetected poor fixation. Finally, the possibility of visually verifying of which structures of the eye have indeed been measured is of great help.

**Conclusion**

The IOLMaster 700 is more effective in obtaining biometric measurements in eyes with less transparent ocular media. The check for decentration or tilt of the crystalline lens, the fixation pattern, and the visualization of the measured structures all help to eliminate potential sources of error and, therefore, to optimize cataract surgery outcomes.

**References**


Full details of this offering can be found on page 10
Femtosecond assisted intrastromal lenticule extraction has become a possibility for corneal refractive surgery. My first experiences with this technology have been outstanding. Coming from initial training with FLEx and entering into SMILE, I would define the technique as the ‘refractive surgery of the corneal surgeon’. It indeed requires surgical expertise and what is valuable is that the skills needed to properly perform the technique can be acquired with a short learning curve.

In addition to the short learning curve, I was surprised by the outstandingly good results. Patients are corrected with a remarkable refractive precision and visual recovery is fast. For me, it was a new experience to achieve patient recovery quickly instead of having some delay. Both spherical and cylinder cornea are properly corrected and so far we have been blessed by a predictability demonstrated by the technique for the range of myopic correction in which it is indicated. Patients are also happy to be corrected by a new technique that minimizes cuts in the cornea.

**SMILE in comparison to Femto-LASIK**

As reported in recent studies and at meetings such as ESCRS and others, our own study confirmed that the outcomes for correcting myopia and myopic astigmatism with SMILE are at least similar to Femto-LASIK. Most probably, the lack of higher order aberrations in high myopia is taking the correction of these highly refractive errors back to corneal procedures instead of phakic IOLs.

Biomechanical mathematical models have demonstrated a potential of better preserving biomechanical stability with SMILE than with Femto-LASIK, which can be attributed to the fact that SMILE is a minimally invasive flapless procedure. Thus, there are associated benefits for future evolution of the eye and lack of progression in the term, as well as the expected and previously demonstrated advantages for the ocular surface. Additionally, the longevity of the postoperative outcomes makes this technique unique for the selection of the correction of myopia and myopic astigmatism.

**Will SMILE using femtosecond technology become the dominant technique?**

The answer is probably yes. I can clearly see a case for using only one laser for corneal refractive surgery. It would be valuable to have a femtosecond laser with a minimally invasive SMILE technique that is capable of treating myopia and hyperopia; performing corneal tunnels for ICR to treat keratoconus patients; relaxing incisions; customized incisions for the diversity of corneal grafts that we perform today; and, most probably, other indications that will arise in the future. I do believe that SMILE will evolve further in the field of refractive surgery and provide benefit for both our patients and our refractive surgery practices.

**References**

3. J.L. Alió et al., ‘Target vs obtained radius of curvature in small incision lenticule extraction (SMILE) and femtosecond lenticule extraction (FLEx)’: Submitted for publication in JCRS.
Humphrey Field Analyzer 3 from ZEISS: Improving on a Standard

By Shareef Mahdavi, SM2 Strategic, Pleasanton, California, USA

The Humphrey Field Analyzer was first launched in 1984 as a means of automating the accurate yet arduous Goldmann manual kinetic perimetry test used to measure defects in the visual field. Over the years, the HFA has become the standard method used to assess and monitor visual field loss. Over 45,000 units are in use worldwide, providing clinicians with a standard platform for measuring, analysing and communicating test results.

In preparation for the launch of HFA3, ZEISS (Dublin, California, USA) placed evaluation units in 19 sites in the US for use with patients over a several month period. SM2 Strategic was asked to survey doctors and technicians at these sites and report on their early impressions of the new platform. 28 users (12 doctors, 16 technicians) completed an online survey at the end of the evaluation period; the summary of findings is shown below.

Evolution of a standard
When first introduced to glaucoma specialists, the HFA was a breakthrough due to its ability to standardize the way a perimeter test was conducted and then analysed. The use of a microprocessor-based device that could be programmed to do a complete analysis of the central 30 degrees of the visual field (while varying the brightness and placement of a Goldmann stimulus) was an early form of automation within ophthalmology.

With the addition of software that could statistically analyse a test and compare it to a database of normal eyes (STATPAC), the HFA forever changed the way that glaucoma patients were diagnosed and managed.

Over the last three decades, the platform has continued to evolve, becoming smaller in size, faster in test speed and easier for physicians to interpret results. With each improvement in hardware and/or software, the HFA has become increasingly indispensable as a tool to assess functional vision. An overview of the major innovations offered by each generation of the HFA platform is shown in Table 1.

HFA3 is the third generation in this product evolution, intended to address the never-ending quest for efficiency within a busy practice. The new platform is designed to address workflow, making tests easier for technicians to setup and administer, and making it easier for doctors to access and analyse data. The HFA3 addresses many of the limitations experienced in earlier versions of the device. A more responsive touchscreen, improved eye tracking monitor, and the introduction of an automatic trial lens (Liquid Trial Lens) are the major hardware features of the new platform. In addition, data collected on the new platform are compatible with test results from earlier generations of the HFA. Numerous comments from the survey underscore the importance of saving time with each and every patient encounter. “The new HFA is much easier to set up and use. It cuts down time for our technicians, especially with the liquid lens,” according to one of the doctors in the survey. An office manager at another clinic noted that “less staff time spent on the ‘little things’ is an obvious benefit.” Users of the ZEISS FORUM data management system note a marked improvement in data exchange between the unit and its interface with FORUM Glaucoma Workplace, allowing PC-based analysis of results. One technician, who appreciated the improved reliability in eye tracking, summarized by saying “all around, HFA3 is a better idea.”

First impressions
In this survey group, highest consideration in evaluating any new diagnostic tool is given to quality (75% of respondents), innovation (50%) and price (36%). The users at the evaluation sites have given high marks to the HFA3, with 75% saying their first impressions have been very positive and 25% somewhat positive. Four in five users (78%) were impressed with the Liquid Lens Technology, with two-thirds of users rating the SmartTouch Interface and the RelEYE Monitor for Gaze Tracking highly. Just under half (46%) gave similar ratings to the FORUM Glaucoma Workplace.

Written positive comments referred to the new modern look and feel of the unit, overall improved ease of use, and how the above hardware features make it a better overall experience for technicians and patients. Overall, these new features combine to allow for faster workflow and the elimination of steps (e.g., having to go to another

![Figure 1: Humphrey Field Analyzer: Innovation Across the Decades](image-url)
room to get a trial lens) that eat up precious minutes during a busy day in clinic.

When asked what HFA3 features did not meet expectations, the highest response was ‘nothing’ (36%) followed by the Liquid Trial Lens (32%). Interestingly, 6 of these 9 users also indicated the Liquid Trial lens was one of their favourite features. This review is to be expected with a unique and novel technology whose goal is to increase reliability and save time. Several comments referenced limitations inherent with visual field testing itself (e.g., blind spot mapping). The validation site users also provided feedback that they would like to see greater functionality in the user interface (e.g., addition of a ‘go back’ button).

As a means of gaining insight into the specific benefits of HFA3, survey users were asked to rate their level of agreement with a series of statements about the platform, ranging from Strongly Agree to Strongly Disagree. The use of a five-point scale provides an efficient means of determining how well the platform is perceived and the intensity of agreement. Overall, there was almost no disagreement, with only one respondent on one statement indicating such. The results of this section of the survey are shown in Table 2.

Summary: The decision to upgrade
Without question, the HFA3 is a much needed redesign of a product that has succeeded by evolving over the past 30 years into the dominant standard in automated perimetry. While there is no additional reimbursement and the visual field test itself is not faster, practices need to recognize that newer often means better in ways that make clinics run smoother and faster. While more difficult to quantify, easier training for new technicians and faster setup and administering of visual fields are of definite value. And the modern unit will integrate better with the growing ‘digital infrastructure’ required (e.g., FORUM) and future advancements in analytics across devices (HFA and OCT).

Is HFA3 a need or a want? We asked this question in the survey and found that for one-half of the survey sample ‘want’ outweighed ‘need’ by a margin of 11 to 3. The other half of the sample indicated it is equally both a need and a want. The ‘bottom line’ sentiment can be found in the two questions regarding the decision to upgrade: 79% indicate they will recommend their own clinic upgrade and 93% would willingly recommend other practices upgrade to HFA3. For practices seeking even greater efficiency and the opportunity to incorporate the latest feature set in their management of glaucoma patients, HFA3 makes sense.

Full details of the HFA3 can be found on page 11

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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</thead>
<tbody>
<tr>
<td>The HFA3 is a significant improvement over HFA II-i</td>
<td>36%</td>
<td>60%</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>The workflow using HFA3 was noticeably faster for technicians to complete</td>
<td>39%</td>
<td>46%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>The overall experience in HFA3 was more comfortable for patients</td>
<td>21%</td>
<td>54%</td>
<td>25%</td>
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</tr>
<tr>
<td>The ability to access data is easier because of the HFA3</td>
<td>43%</td>
<td>39%</td>
<td>18%</td>
<td></td>
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<tr>
<td>The ability to analyze data is easier because of HFA3</td>
<td>41%</td>
<td>52%</td>
<td>7%</td>
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<tr>
<td>The user interface is easier for technicians to administer tests</td>
<td>42%</td>
<td>54%</td>
<td>4%</td>
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<tr>
<td>The Liquid Lens technology is a significant improvement over the trial lens</td>
<td>43%</td>
<td>35%</td>
<td>18%</td>
<td>4%</td>
</tr>
<tr>
<td>I recommend our clinic/practice upgrade to the HFA3</td>
<td>29%</td>
<td>50%</td>
<td>18%</td>
<td>4%</td>
</tr>
<tr>
<td>I would willingly recommend the HFA3 to my colleagues at other practices</td>
<td>37%</td>
<td>56%</td>
<td>7%</td>
<td></td>
</tr>
</tbody>
</table>

(N = 28, 12 = Ophthalmologist/Optometrist, 16 = Technician/Administrator)
AngioVue OCTA system

The leader in Spectral-Domain OCT innovation has revolutionized ocular structure assessment once again.

Introducing AngioVue
The AngioVue OCTA system is a non-invasive, dyeless technique for visualizing the presence of ocular bloodflow in the vessels. Unlike other imaging methods which use contrast agents, AngioVue allows visualization of vasculature within specific layers of the retina, without the blurring or obscuring effects of staining or pooling.

5 Essential Technologies
The unique combination of five important components make AngioVue a clinical reality.

- High-speed spectral-domain OCT (70000 A-scans/sec).
- Patented Motion Correction Technology (MCT) to improve image quality.
- Patented Split Spectrum Amplitude Decorrelation Algorithm (SSADA) to enable efficient scan acquisition.
- CUDA parallel processing architecture to reduce processing time.
- Patented en face visualization of 3D OCT data.

Offering OCT Angiography scanning of 3 x 3 mm, 6 x 6 mm and 8 x 8 mm of the retina, and 3 x 3 mm or 4.5 x 4.5 mm of the optic disc, the analysis reports present side-by-side OCT angiography and OCT structure (en face) results derived from the same data. En face OCTA images of the superficial vascular plexus, deep vascular plexus, outer retina and choroid vesel area can be displayed for assessment and adjusted by the clinician for optimal viewing of the desired area within the 3D volume.

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**IOLMaster 700 from ZEISS**

The new IOLMaster 700 from ZEISS with SWEPT Source Biometry allows irregular geometries of the eye or insufficient fixation to be already identified during the diagnosis. Apart from optical biometry, it also offers OCT imaging across the entire length of the eye. The ZEISS IOLMaster 700 enables cataract surgeons to view the complete longitudinal section of the eye, from the cornea to the retina. Irregular eye geometries, for example tilting of the lens axis, are therefore easier to identify. It is expected that this will facilitate a reduction in refractive surprises.

The unique Fixation Check provides more confidence in biometry. Surgeons can now reduce the risk of refractive surprises due to incorrect measurements caused by undetected poor fixation. Compared with previous procedures, in which the measurement result was derived from an A scan curve, the image-based measurement with the ZEISS IOLMaster 700 brings both physician and patient added safety, as the expected refractive outcome can be more reliably predicted.

As with the ZEISS IOLMaster 500, this new device also simplifies the workflows prior to cataract surgery. The Reference Image eliminates the need for manual pre-operative and intraoperative marking of the astigmatism axis on the patient’s eye before implantation of a toric IOL, as well as manual data transfer. Both were previously necessary for alignment of the toric lenses.

The ZEISS IOLMaster 700 is fully compatible with previous versions and provides access to the database of the User Group of Laser Interference Biometry (ULIB). This database contains the lens constants of more than 270 IOL models and is based on more than 50,000 cataract operations. The unique telecentric keratometry allows particularly robust and reproducible measurement of the corneal surface.

**SMILE — 3rd Generation of Laser Vision Correction**

Small incision lenticule extraction or SMILE is redefining refractive surgery. Only 3.5 years after its international launch, the SMILE procedure has been established in the market as the 3rd generation laser vision correction beyond PRK and LASIK. This unique, flapless and minimally invasive procedure has now been successfully performed in all major markets.

SMILE is based on the removal of a tissue disc (called lenticule) instead of tissue ablation, distinguishing it from PRK and LASIK. An excimer laser is not required. Unlike LASIK, the SMILE procedure is performed without a flap. ZEISS is at the forefront of the 3rd generation laser vision correction method with the flapless, minimally invasive ReLEx SMILE. The refractive lenticule is created in the intact cornea, using the femtosecond laser system VisuMax from ZEISS. Refractive correction is achieved by extracting the lenticule through a small incision.

ReLEx SMILE offers several advantages over traditional refractive techniques. Due to the use of femtosecond cutting instead of ablation, it enables a refractive correction which is not affected by ambient room conditions or corneal hydration and leads to excellent predictability, also for higher corrections.1,2 As the procedure is flapless, the upper corneal layer and nerve tracts of the cornea remain largely intact. Therefore, dry eye syndrome is less likely to occur compared to LASIK.2–5 Furthermore, the small incision lowers the incidence of infection and epithelial ingrowth, and the healing of the cornea is better.5

ReLEx SMILE is approved for the correction of myopia (up to –10.00 D) and myopic astigmatism (up to –5.00 D) up to an SEQ of –10.00 D and offers major future potential for broadening the indication range.

**References**

Humphrey Field Analyzer 3 from ZEISS

The new Humphrey Field Analyzer 3 (HFA3) from ZEISS, is the next generation in visual field testing and analysis. The HFA3 is designed to accelerate clinic flow while delivering the same gold-standard testing strategies and test patterns. The New HFA3 provides a streamlined and faster workflow with an array of new features designed to:

• Reduce setup time with a single trial lens. Using liquid pressure, the new Liquid Trial Lens instantly delivers each patient’s refractive correction with the touch of a button.*
• Save time with an intuitive new SmartTouch interface, which reduces the number of steps required for the technician to start a perimetry exam.
• Accelerate clinic flow with equipment that can be learned quickly and operated easily.
• Improve confidence in test results with RelEYE, which allows doctors to instantly review the patient’s eye position, at any stimulus point. RelEYE data is available on the instrument and when reviewing test results with FORUM Glaucoma Workplace.
• Simplify test administration, with an easy-to-use kinetic graphical user interface with a full 180-degree field of view.

*Some patients may require a separate lens. Liquid Trial Lens available on the HFA3 model 860.

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