A new era approaches.

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Until very recently, every LASIK procedure was performed with the ablation profile calculated on an eye with Gullstrand's eye model dimensions. As of this writing, fewer than 10,000 eyes have been treated with a WaveLight excimer laser platform (Alcon) equipped with wavelight plus software (Alcon) that was launched commercially earlier this year. The software makes use of a digital twin to refine the ablation pattern *in silico* before it is applied to the eye. This article explains how the software works, its results to date, and its potential.

HOW THE SOFTWARE WORKS

Not many know that the ablation profile for almost every laser vision correction (LVC) procedure performed to date has been calculated based on Gullstrand's schematic eye model, for which he won the Nobel Prize in Physiology or Medicine in 1911. His eye model predates the invention of the laser by around 50 years (1960) and LVC by more than 70 years (1983).

To date, irrespective of the ablation profile being used (wavefront-guided, topography-guided, asphericity-guided, or wavefront-optimized driven by a manifest refraction input), the excimer laser platform's calculation of the ablation profile assumes that the eye about to be treated is Gullstrand's model eye, which has an axial length of 24 mm and keratometry readings of 43.00 D. An eye with Gullstrand's dimensions (43.00 D corneal power and

24 mm axial length) is very likely to be emmetropic or close to emmetropic. In contrast, ametropic eyes—those with refractive errors—often have corneas that are either flatter or steeper than 43.00 D and axial lengths shorter or longer than 24 mm. Currently, the wavelight plus profile is indicated only for myopic eyes, meaning that most patients treated with this profile have axial lengths of 23–24 mm or greater.

No nomogram is required with wavelight plus. Diagnostic data such as Scheimpflug corneal tomography, an ocular wavefront measurement, and axial length biometry are captured by the SightMap diagnostic platform (Alcon). From these data, the software constructs a digital twin of the patient's eye. The software then generates an ablation profile to reshape the anterior cornea to correct myopia and myopic astigmatism. The digital twin eye avatar (or *eyevatar* as some call it) also uses data to account for the epithelial remodelling and biomechanical effects expected with a myopic correction.

Ray Tracing

The ablation profile created should be the best possible because it has been designed specifically for the eye to be treated rather than for the Gullstrand model eye. The process, however, is not finished. Ray tracing is applied to the digital twin. If the planned treatment is perfect for the eye, all 2,000 incoming beams of light will converge on the fovea. This is not typically the case.

Ray tracing all the aberrant beams from the retina back through the eye's optical system to the anterior cornea indicates how the cornea should be ablated. This process is repeated until all the incoming light rays converge on the fovea. Once the perfect *in silico* treatment profile has been established, the ablation pattern is ready for use on the patient's eye.

The iterative ray-tracing process took up to 6 hours in 2010 when the original study was performed.[1,2] At that time, three separate devices were used to capture the data required to create a 3D eye model. Today, measurements are captured with just the SightMap device, typically within 4 to 5 minutes per eye. The iterative ray-tracing process with the WaveLight EX500 portal software (Alcon) usually takes less than 30 seconds.

If the data are not used for a ray-tracing procedure, the LVC procedure may be changed to a wavefront-optimized or Custom-Q (Alcon) treatment.

Results to Date

LVC using wavelight plus has been performed on 5,000 eyes in China, more than 2,000 eyes in Australia, and approximately 2,000 eyes in Europe. All the eyes have achieved 20/20 UCVA; 81%, 51%, and 8% have achieved a UCVA of 20/16, 20/12.5, and 20/10, respectively.[3] These are monocular outcomes. Patients' binocular UCVA has been even better.

APPLICATIONS BEYOND REFRACTIVE SURGERY

In the future, the principles used by the wavelight plus software may be applied to LVC for hyperopia and hyperopic astigmatism. Given how well the 3D personalized eye model works, it could also be used to plan presbyopia treatment by introducing a specific amount of spherical aberration into the optical system and extending the eye's depth of focus.

The digital twin or 3D personalized eye model could also increase the accuracy with which the final IOL position is predicted. When this information is combined with AI-assisted technologies in development, IOL outcomes may approach the level of accuracy achieved with LVC (ie, most eyes within ±0.25 D of the refractive target and nearly all within ±0.50 D). ■

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2. Cummings AB, Kelly GE. Optical ray tracing-guided myopic laser in situ keratomileusis: 1-year clinical outcomes. *Clin Ophthalmol*. 2013;7:1181-1191.
3. He G, Bala C. Ray-tracing-guided myopic LASIK: real-world clinical outcomes. *J Cataract Refract Surg*. 2023;49(11):1140-1146.

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