GLOBAL MEDICAL AFFAIRS
science matters

Alcon

WHITE PAPER

SIGHTMAP & WAVELIGHT PLUS TECHNOLOGY

INMA PEREZ-GOMEZ, MCOPTOM, PHD[1]
SISSIMOS LEMONIS, STATE CERTIFIED ENGINEER (EQUIV. BSC)[2]

1. ALCON MEDICAL AFFAIRS, INTERNATIONAL, GENEVA, SWITZERLAND
2. ALCON CLINICAL REFRACTIVE DEVELOPMENT, GLOBAL, FREIBURG, GERMANY

WAVELIGHT PLUS TECHNOLOGY

INMA PEREZ-GOMEZ, MCOPTOM, PHD
SISSIMOS LEMONIS, STATE CERTIFIED ENGINEER (EQUIV. BSC)

KEY TAKEAWAY POINTS

- Wavelight plus is an evolution in creating an ablation profile by representing the pre-operative eye using a virtual 3D eye model constructed using multiple data sources.
- The data to create the 3D eye model are derived from a single diagnostic device that integrates a Scheimpflug tomographic apparatus, a Hartman-Shack wavefront sensor, and partial coherence interferometry biometer.
- In contrast to current technologies, the wavelight plus ablation algorithm additionally simulates and optimizes the post-operative anterior corneal surface within the 3D eye model to achieve the intended correction while considering geometric and optical properties of the individual eye. These include corneal anterior and posterior curvature, total ocular wavefront, the effect of anterior chamber depth to the ray tracing, anticipating anterior surface of the crystalline lens and axial length.
- The new ablation algorithm includes compensation for peripheral laser ablation efficiency, epithelial remodeling, and biomechanical influences that can observed with standard LASIK.

INTRODUCTION

The majority of corneal refractive surgical interventions remove corneal volume that is either aiming to correct for lower order aberration namely sphere and astigmatism or a combination of lower and higher order aberrations in one united profile.

Approaches to calculate LASIK treatment profiles have evolved over the years to include developments such as pre-compensation algorithms for laser ablation efficiency in the peripheral cornea and algorithms to either avoid inducing aberrations or even to reduce higher-order aberration.[1] Theoretical models did reveal limitations[2] in applying such algorithms and clinical studies did not conclusively prove for all patient cohorts[3-6] the capability to not induce new aberrations or reduce higher order aberration vs pre-operative.

Unlike the currently available ablation volume calculation algorithms, wavelight plus uses a new approach to create the ablation profile by using a 3D eye model (Figure 1) to represent the major optical and geometrical components of the individual eye and employing ray tracing to simulate the path of light through the cornea to the retina.

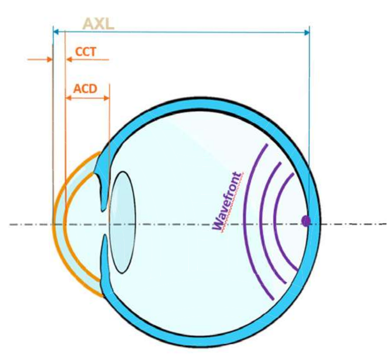

Figure 1: 3D eye model overview

Technology	Derived Data
Hartmann-Shack Wavefront sensor	Ocular Wavefront
Scheimpflug Imaging	Crystalline lens position ACD
	Topography of anterior corneal surface
	Topography of posterior corneal surface
	Corneal thickness map & CCT
Partial coherence Interferometry	Axial length of the eye (AXL)

This white paper provides a description of the technology behind wavelight plus Wavelight system to be used with the wavelight EX500 excimer laser.

CREATING THE WAVELIGHT PLUS 3D EYE MODEL

The data derived by the wavelight plus Sightmap diagnostic device are used by the wavelight plus algorithm to create the 3D eye model. The wavelight plus Sightmap is a 3 in 1 diagnostic device with the capability to measure the wavefront, Scheimpflug tomography, and biometry (Figure 2) in consecutive exams.

Figure 2: Wavelight plus Sightmap diagnostic device

THE SIGHTMAP DIAGNOSTIC DEVICE

1. Hartmann–Shack wavefront sensor

The Hartmann–Shack wavefront sensor generates an individualized wavefront map formed by the optical components of the eye (cornea, anterior chamber, crystalline lens and vitreous).

A Hartmann–Shack wavefront sensor consists of an array of lenses focused on a photo sensor (charge-coupled device, CCD).[7] As an infrared (IR) laser beam is projected through the pupil onto the retina, the reflected light passes through a micro-lens array, where reflection is seen as a point source, before being detected by the sensor. The deviation of each lenslet's focal point from its ideal reference position is used to

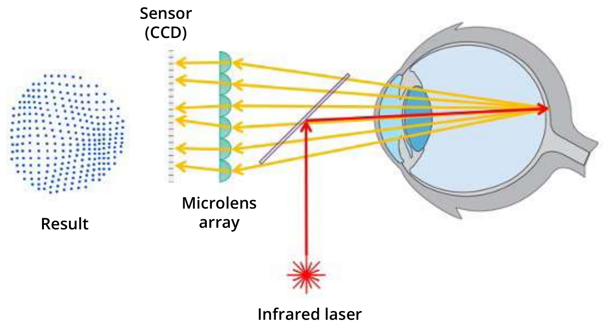

Figure 3: Hartmann–Shack wavefront sensor principle CCD, charge-coupled device; IR, infrared.

calculate the aberrations of the eye, creating an individualized wavefront map with a minimum pupil diameter of 4.5 mm (Figure 3).[8,9]

The wavefront map identifies both lower order aberrations, such as tilt, sphere (myopia and hyperopia) and astigmatism, and higher order aberrations, such as coma and spherical aberration. The wavelight plus Sightmap incorporates all aberrations into the 3D eye model.

2. Scheimpflug corneal tomographer

The Scheimpflug principle is used to enable large depth of focus during image capture of the anterior segment from the cornea to the posterior surface of the crystalline lens simultaneously.

A rotating Scheimpflug camera then takes a series of 25 sectional images from the side view, which stack to build an image of the anterior eye.[8] This data is used to develop the 3D eye model, which includes topography of the anterior and posterior corneal surfaces, pachymetry across the entire corneal surface from limbus to limbus, and anterior chamber depth (Figure 4).[8,11] An infrared image of the undilated iris is also captured to support iris registration and cyclo-torsional alignment at the excimer laser.

3. Partial coherence interferometry captures biometric parameters

The measurement of the eye's axial length is performed once using a technique called partial coherence interferometry. This process involves taking six measurements at once, spanning from the front surface of the cornea to the retina. The software determines the axial length by analyzing the position of the reference mirror. (Figure 5).[7]

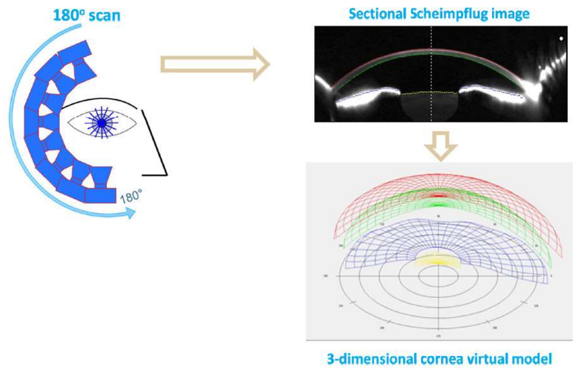

Figure 4: Scheimpflug imaging - Corneal cells scatter the slit light and a sectional image is taken from a camera perpendicular to the light (A). A scan of the eye results in thousands of data points, which are used to create a 3D virtual model of the anterior segment (B) from which resulting measurements are made (C).

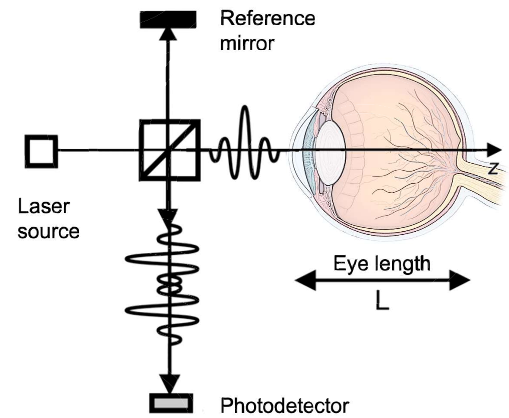

Figure 5: Partial coherence interferometry - A laser is projected into the eye and the reflection onto a photo-detector provides the axial eye length.

CREATING THE WAVELIGHT PLUS EYE MODEL AND ABLATION PROFILE

Currently, classic LASIK treatments, such as WAVEFRONT OPTIMIZED™ and CUSTOM Q™, and customized ablation profiles, such as topography-guided, and wavefront-guided, are calculated based on data derived from separate diagnostic devices or in combination with manifest refraction. The respective diagnostic data are applied to a simplified corneal curvature ablation algorithm which in return creates an ablation profile to achieve a corneal curvature corresponding to emmetropia.

Wavefront-guided treatments measure the ocular low and high-order aberrations of the eye in its entirety and topography-guided treatments consider the anterior corneal shape that contribute to these same aberrations. However, these ablation profiles do not consider the spatial and geometrical position of the various optical elements of the eye in the calculation of the ablation.[11,12]

This personalised calculated ablation profile may also be pre-compensated to avoid induction of rotation-symmetric aberrations, predominantly spherical aberration Z_0^4.

In contrast, the wavelight plus algorithm creates ray tracing-based ablation profile using the following steps:

1. Create an ablation profile

   a. The fundamental 3D eye model is constructed using data obtained from the Sightmap. This model encompasses various components, including the complete cornea (comprising the anterior cornea, pachymetry, and posterior cornea), the anterior chamber depth, and the axial length of the eye. The model incorporates up to 2,000 rays of light to simulate their trajectory through these surfaces. Additionally, the properties of the crystalline lens are defined based on an existing model.[11]

   b. The anterior curvature of the crystalline lens is adjusted iteratively to accurately represent the measured ocular wavefront, taking into account both low and high-order aberrations. Through a series of iterations, the lens curvature is fine-tuned to match the observed wavefront, ensuring a more precise representation of the eye's optical properties.

   c. Create an ablation profile targeting emmetropia.

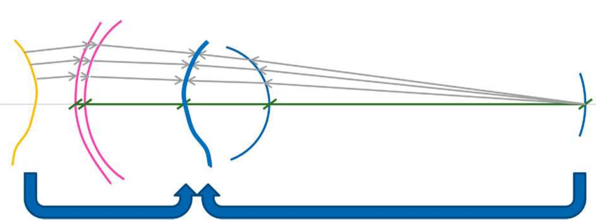

Figure 6

2. Test and optimize the ablation profile

a. The pre-operative anterior corneal topography is amended by the previously calculated ablation profile simulating the post-operative anterior corneal surface.

b. The ray tracing algorithm then simulates the post-operative achieved correction and iteratively optimizes the pre-operative anterior corneal surface in the 3D model to the best possible correlation.

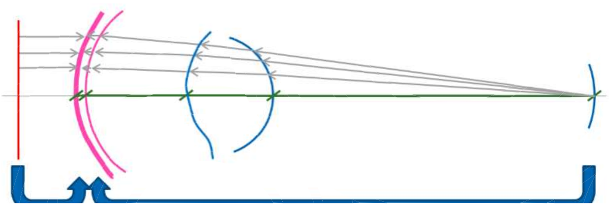

Figure 7

3. Apply wavelight plus pre-compensation

The updated wavelight plus algorithm utilizes accumulated preoperative and achieved data to perform calculations. This novel pre-compensation algorithm enables real-time determination of the required pre-compensation for each individual, considering their specific characteristics and previously tested profile.

The wavelight plus pre-compensation method will account for rotationally symmetric aberrations but also for non-symmetric aberrations taking laser efficiency, long-term epithelial healing and biomechanical changes in order to obtain a post operative corneal surface that matches the previously simulated model by the algorithm.[13]

REFERENCES

1. Mrochen M, Donitzky C, Wüllner C, Löffler J. Wavefront-optimized ablation profiles: Theoretical background. *J Cataract Refract Surg* 2004; 30:775–785.
2. Manns F, Ho A, Parel J-M, Culbertson W. Ablation profiles for wavefront-guided correction of myopia and primary spherical aberration. *J Cataract Refract Surg* 2002; 28:766–774.
3. Summary of safety and effectiveness data (SSED). WaveLight ALLEGRETO WAVE Excimer Laser System and the ALLEGRO Analyzer. P020050/S004
4. Summary of safety and effectiveness data (SSED). VISX STAR S4 Excimer Laser System and WaveScan WaveFront System. P930016/S016
5. Summary of safety and effectiveness data (SSED). STAR S4 IR Excimer Laser System iDesign Advanced WaveScan Studio System. P930016/S044
6. Summary of safety and effectiveness data (SEED). iDESIGN Refractive Studio and STAR S4 IR Excimer Laser Systems. P930016/S057
7. Cruickshank FE, Logan NS. Optical 'dampening' of the refractive error to axial length ratio: implications for outcome measures in myopia control studies. *Ophthalmic Physiol Opt* 2018;38:290–297.
8. Alcon Research LLC. WaveLight® global product guide. 2020.
9. WaveLight GmbH. WaveLight® EX500 Wavelight plus™ quick user manual. 66722033.2019.
10. WaveLight GmbH. WaveLight® Wavelight plus™ Sightmap diagnostic device user manual. 1089.2020.
11. Mrochen M, Bueeler M, Donitzky C, Seiler T. Optical ray tracing for the calculation of optimized corneal ablation profiles in refractive treatment planning. *J Refract Surg* 2008;24:S446-451.
12. Schumacher S, Seiler T, Cummings A et al. Optical ray tracing-guided laser in situ keratomileusis for moderate to high myopic astigmatism. *J Cataract Refract Surg* 2012;38:28-34.
13. Bueler M, Mrochen M. Computer program for ophthalmological surgery. United States Patent Application Publication 2008;US 2008/0033408 A1.

VIEW OR DOWNLOAD OTHER WHITE PAPERS AT **ALCONSCIENCE.COM**

Alcon | GLOBAL MEDICAL AFFAIRS

Refer to operator manual for indication, contra indication, and warnings

 p-MED-IN-WLO-250001