

IOL calculation after myopic laser refractive surgery – the *Haigis-L* formula

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Background

Eyes after corneal refractive surgery will be an increasing challenge for IOL calculation in the years to come. This is due to the refractive power of the cornea, which – because of the altered corneal structure by laser surgery – cannot be measured or deduced correctly with today's measurement procedures and instruments. Furthermore, in some popular IOL power formulas, corneal power is incorrectly processed. Basically, three sources of error can be identified[1]:

1. The measurement of the anterior corneal radius is systematically incorrect, since it is not performed on the central cornea, but more peripherally. After myopic laser surgery, the measured radius of curvature will be too small.
2. A second independent error results from the usually applied derivation of corneal power from the measured anterior radius. In doing so, a constant ratio of anterior to posterior radius (e.g. Gullstrand-ratio: 7.7/6.8) is implicitly assumed. This ratio, however, has been deliberately changed by the refractive procedure. After laser correction for myopia, both errors will lead to an overestimation of the power of the cornea thus causing an underestimation of the necessary IOL power.

3. In some IOL formulas (*SRK/T*, *Holladay-1*, *HofferQ*) a third error with the same effect is created ([1], [2]) by the formula-specific prediction algorithms for the postoperative effective lens position (ELP), which make use of corneal power. Smaller corneal powers after ractive surgery will produce IOL positions more anteriorly in these formulas; hence IOL powers will again be too small.

Errors of the 1st and 2nd type can be avoided if the refractive history method ([3], [4]), which is widely acknowledged as gold standard, can be applied. For this purpose, keratometry data prior to the refractive procedure as well as the exact knowledge of the achieved change in refraction is necessary. If this information is not available, there is presently no satisfactory general solution for this 'no-history' situation. Errors of the 3rd kind can be avoided if an IOL formula is used which does not utilize corneal power as a predictor for the ELP.

The *Haigis-L* formula addresses the above described problems and offers a solution based on current *Zeiss IOLMaster* keratometry.

Determination of effective corneal power

The error introduced by the radius measurement depends essentially on the instrument used, the amount of refractive correction achieved and laser and ablation types applied. From the refractive history method the effective anterior corneal radius can be derived [5] and correlated with the measured radius (Fig.1, [6]).

In principle, a thick lens calculation can then be carried out if certain assumptions about the posterior corneal surface are made. Possible new problems arising from these assumptions can be avoided by a more direct approach correlating the effective corneal power (determined from the refractive history method) with the measured radii. Fig.2 shows typical results obtained with the *Zeiss IOLMaster*. Corneal powers derived from this graph are free of the above described errors of the 1st and 2nd type.

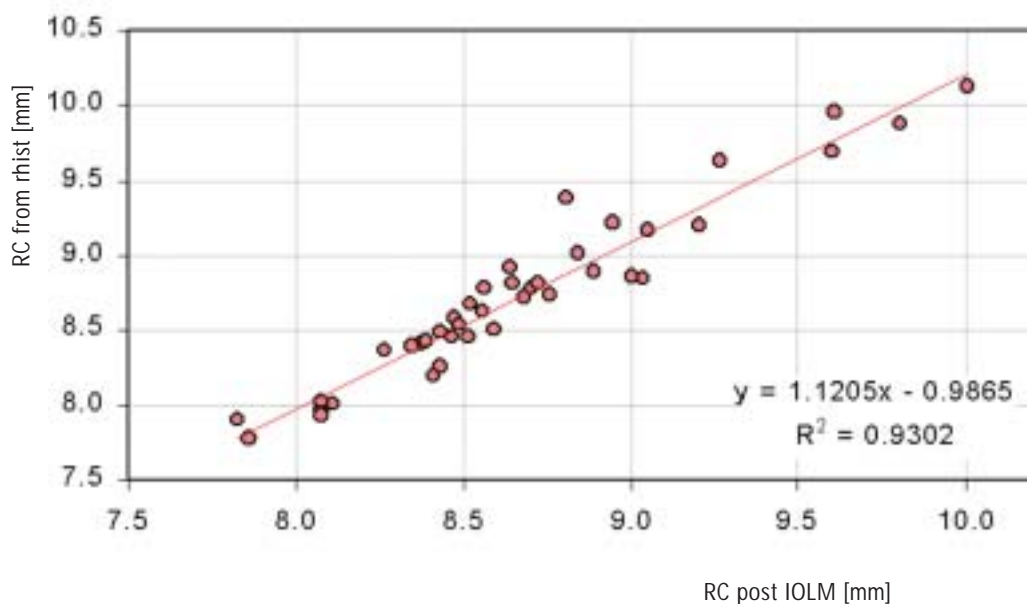


Fig. 1
Effective corneal radius derived from the refractive history method vs currently measured corneal radius with the *Zeiss IOLMaster* after myopic LASIK with a Schwind Keratom

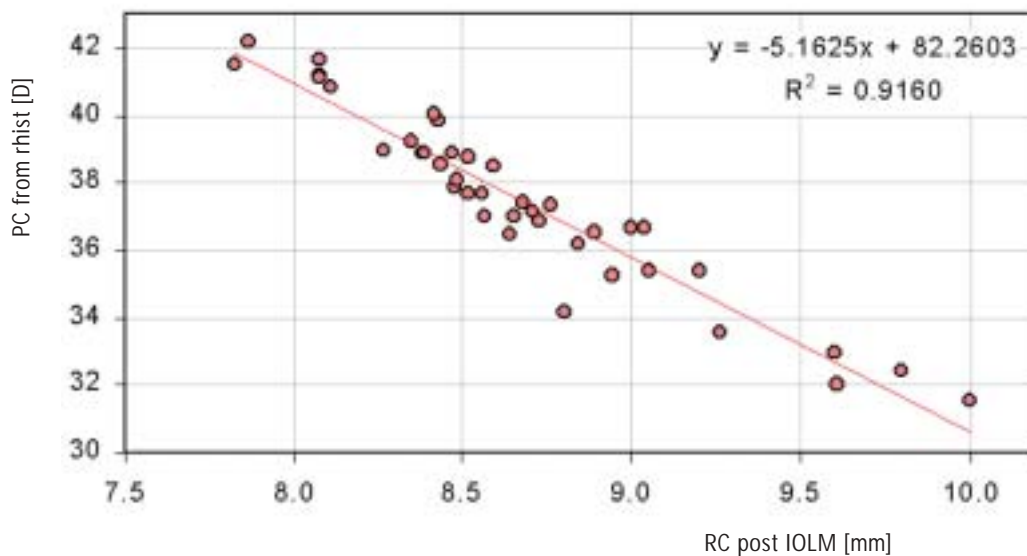


Fig. 2
Effective corneal power derived from the refractive history method vs currently measured corneal radius with the *Zeiss IOLMaster* after myopic LASIK with a Schwind Keratom

Selection of IOL power formula

The *Haigis* formula [7] does not make use of the corneal power to predict the postoperative lens position and is therefore not compromised by a formula-specific error as the other IOL power algorithms mentioned above. In model calculations [1] simulating myopic LASIK with subsequent IOL implantation in axially myopic eyes of -5 D and -10 D the smallest overall errors were found for the *Haigis* and the *HofferQ* formulas. To allow comparison, the lens constants for all formulas had been optimized to produce the same power for the 'normal' (Gullstrand) model eye.

From Fig.3 it can be seen that – dependent on the former degree of myopia – residual errors of 0.1 to 0.5 D are left for the *Haigis* formula, while these errors amount to 1.8 to 3.2 D for SRK II. The small remaining errors in the *Haigis* formula are considered to be mainly due to the different axial length ranges used for constants' optimization and IOL determination in the model calculations. Combining this formula with a small correction factor for the described residual error and the IOLMaster correction curves treated earlier results in an algorithm – the *Haigis-L* formula – which allows IOL calculation after myopic laser surgery solely based on present *IOLMaster* measurements.

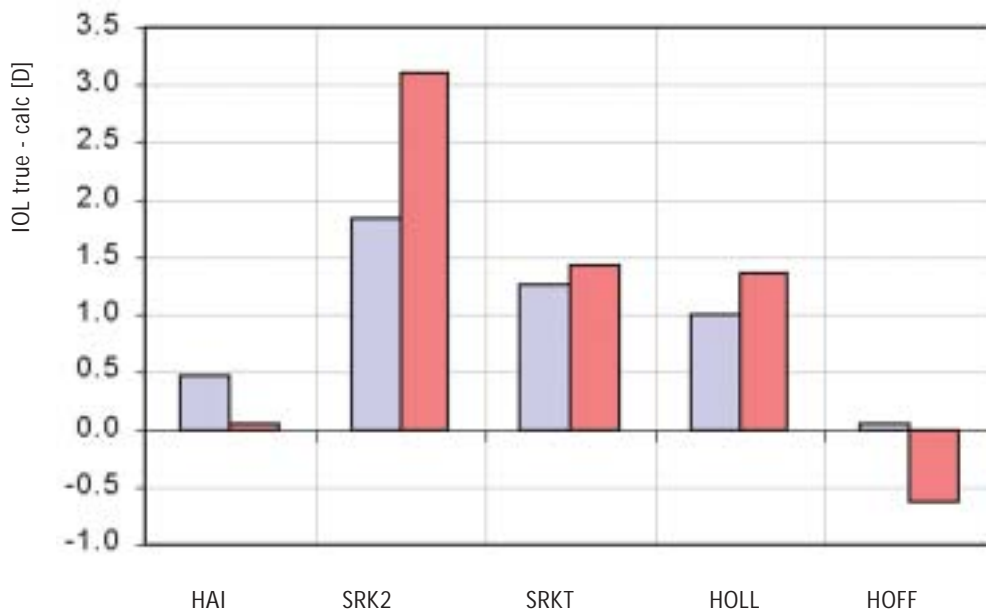


Fig. 3

Model IOL calculation after simulated myopic LASIK with corneal power calculated from the refractive history method for eyes formerly -5 D (myo 05 pL) and -10 D (myo 10 pL): differences between necessary IOL power for emmetropia and calculated powers using different IOL formulas

■ myo 05 pL
■ myo 10 pL

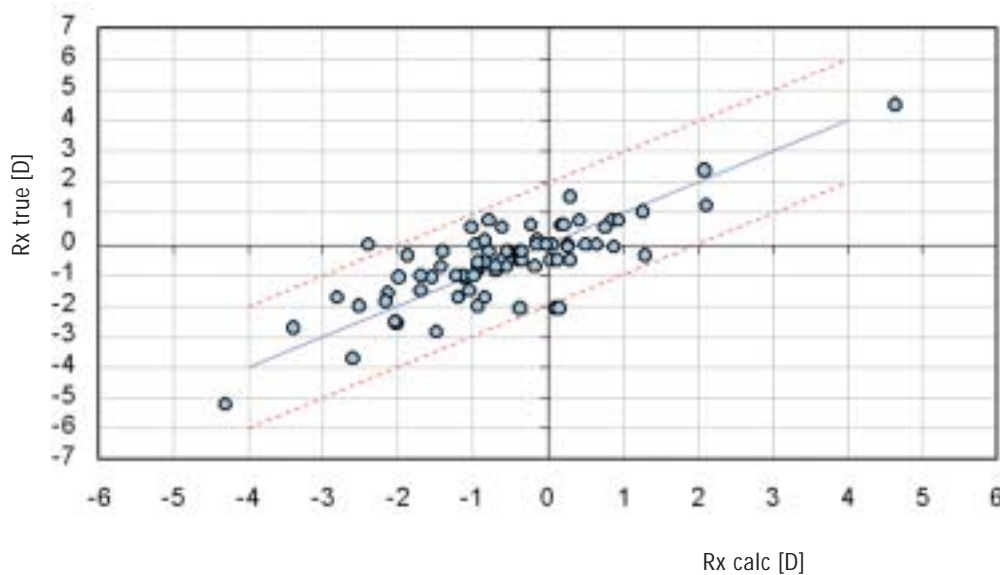


Fig. 4

Achieved stable postop refraction (spherical equivalent) vs calculated refraction using the *Haigis-L* formula. Oblique lines denote the ± 0 and ± 2 D limits. Correlation coefficient: 0.800

Clinical check of the Haigis-L algorithm

To evaluate the performance of the new formalism, 77 cases of IOL implantation after myopic LASIK or PRK were retrospectively analyzed [8]. Surgeries were performed by 30 different surgeons. A total of 20 different IOL types was implanted, among them 18 x Alcon SA60, 14 x AMO AR40e, 9 x Alcon SN60. In each case, biometry (axial length, anterior chamber depth) and keratometry (corneal radii) measurements were carried out with the Zeiss IOLMaster prior to cataract surgery. Stable postoperative manifest refraction was determined by each facility. All 77 eyes had a postoperative BCVA > 0.3.

The average spherical equivalent prior to corneal surgery had been -9.2 ± 3.6 (-18.1 ... -4.2) D (n=30), the means (n=77) for axial length, anterior chamber depth and corneal radii were 27.42 ± 2.19 (23.09 ... 34.26) mm, 3.49 ± 0.41 (2.43 ... 4.39) mm, 8.77 ± 0.57 (7.42 ... 10.77) mm.

The Haigis-L formula was applied to predict the postoperative refraction Rx calc, which was then compared to the actually achieved stable subjective refraction Rx true at BCVA. Fig.4 shows the dependence between Rx true and Rx calc with a high correlation coefficient of 0.800. Only 3 cases (3.9%) lie outside the ± 2 D margin ($\Delta Rx = Rx \text{ true} - Rx \text{ calc} = -2.30, -2.23, +2.40$ D). The following results were obtained for the refractive prediction error ΔRx : mean arithmetic error: 0.00 ± 0.83 (-2.30 ... +2.40) D, mean absolute error: 0.62 ± 0.55 (+0.01 ... +2.40) D. The percentages of correct refraction predictions within ± 2 , ± 1 and ± 0.5 D were 96.1%, 79.2% and 51.9%.

Prepared for publication.

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