IOL Power Calculation After Myopic LASIK

Hany Helaly,
Lecturer of Ophthalmology,
Faculty of Medicine,
Alexandria University.
Prof. Dr. Mohammad El-Hifnawy
Professor of Ophthalmology
Faculty of Medicine
Alexandria University

Prof. Dr. Mohamed Shafik
Professor of Ophthalmology
Faculty of Medicine
Alexandria University

Dr. Amro Abou El-Kheir
Assistant Professor of Ophthalmology
Faculty of Medicine
Alexandria University
IOL power calculation following myopic LASIK

• There is an increasing number of cataract surgeries in eyes after LASIK.
• IOL power calculation turned out to be problematic.
IOL power calculation following myopic LASIK

• Measured average k-reading + standard IOL power calculation formulas → overestimation (postop. hyperopia)
IOL power calculation following myopic LASIK

• After myopic LASIK: postop. hyperopia
• After hyperopic LASIK: postop. myopia

• Error 1 D in IOL power $\rightarrow$ 0.71 D error at the spectacle plane

Causes of Error in estimating corneal power after excimer laser corneal surgery

- Keratometers & Topography devices measure anterior surface of central cornea.
- K in (D) is derived from r in mm measured using an effective refractive index to falsely consider a single refractive lens representing anterior and posterior surfaces.
Causes of Error in estimating corneal power after excimer laser corneal surgery

- This effective refractive index is considered valid as long as radii of anterior and posterior surfaces of the cornea are proportionate and resembles that of the model eye.
- RI is a standardized value (1.3375 in most keratometers and CVK devices).
Causes of Error in estimating corneal power after excimer laser corneal surgery

- r of anterior surface is considerably increased and distance between both refractive surfaces is decreased.
- Therefore, calculating keratometric diopters from anterior radius of curvature is not accurate.
Formula error

• The estimation of effective lens position (ELP) by the third- or fourth-generation formulas is not correct when the postoperative corneal power values are used.
Formula error

• Most 3rd generation theoretical formulas (e.g. SRK/T, Holladay) use AL & corneal power values to predict ELP.

• Problem: “two-variable prediction” formulas rely on AL & central corneal power to predict ELP.
Formula error

• These formulas assume:
  – The longer the axial length or steeper k values, the deeper the anterior chamber.
  – The shorter the axial length or flatter k values, the shallower the anterior chamber.
Advances in IOL power calculation formulas after keratorefractive surgery

- The double-k formula.
- Holladay 2 formula.
- Haigis-L formula.
- Shammas-PL formula.
The double-k formula

• For 3rd generation formulas:
  – SRK/T.
  – Holladay 1.
  – Hoffer Q.

• This method uses 2 k-values:
  – *pre refractive* for calc of ELP
  – *post refractive* for the vergence formula that finally gives the IOL power
Holladay 2 formula

- Uses another innovative approach, which is to use measurements of
  - corneal power.
  - corneal diameter.
  - anterior chamber depth (ACD).
  - lens thickness.
  - refractive error.
  - axial length.

to further refine the ELP calculation.
Haigis-L formula

- Using a correction curve to correct the current IOLMaster measurement of corneal radius to derive the effective equivalent corneal power.

\[ r_{corr} = \frac{331.5}{(-5.1625 \times r_{meas} + 82.2603 - 0.35)} \]

- Then enter it into the regular Haigis formula.
Shammas-PL formula

• Shammas described a corneal power correction method that uses only data available at the time of cataract surgery (i.e. post-LASIK K-readings).

• $K_c = (1.14 \times K_{post}) - 6.8$
Shammas-PL formula

• This corrected K-value is used in the Shammas post-LASIK (Shammas-PL) formula.

• In which the ELP does not vary with the corneal curvature that has been altered by the LASIK procedure.
• There are many methods to calculate intraocular lens power after keratorefractive surgery, indicating that there is no single accurate measure that can be reliable to perform this task.
The aim of this work was to:

• Evaluate the **accuracy of corneal power measurements** for intraocular lens power calculation after myopic LASIK.
• Try to **deduce a regression formula** for IOL power calculation after myopic LASIK.
Subjects and Methods

• A clinical study that included 45 eyes of 37 patients with previous myopic LASIK who were scheduled for cataract surgery.
Exclusion criteria:

– Complicated cataract surgery.

– Corneal pathology e.g. corneal opacities.

– Refractive surgery complications e.g. flap related complications, abnormal healing.
Evaluation of the patients included

1- Complete History taking including refractive history.
2- Complete ophthalmologic examination.
3- Measuring k values by different methods.
4- AL & ACD were obtained from IOLMaster optical biometer.
Measuring k values by different methods

1- Manual keratometry.
2- Auto-keratometery.
3- Pentacam.
4- IOLMaster.
In this way, different k values were obtained

- Manual k values.
- Automated k values.
- IOLMaster k readings.
- Calculated k readings from clinical history method (if available data).
- Pentacam derived k values:
  - Sim-k.
  - Holladay EKR at 1 mm, 2 mm, 3 mm, 4 mm, and 4.5 mm.
  - True net power.
• Routine phacoemulsification + foldable IOL in the bag was performed through clear corneal tunnel incision
The implanted IOL type was either:

- **Hydrophobic acrylic IOL** (Acrysof SA60AT, Alcon Surgical Inc., Fort Worth, TX)
- **Hydrophilic acrylic IOL** with an A-constant value of 118:
  - CIMflex42, Cima technology Inc., Pittsburg, PA
  - SC25-FOLD, Eyekon Medical Inc., Clearwater, FL
  - OcuFlex ANU6, Polymer Technologies International, Gujarat, India
– Final refraction was obtained one to four months after the surgery.

– Most eyes (55 eyes) were examined during the second month, while the rest of the eyes (5 eyes) were examined during the third and the fourth months.
To calculate IOL power for post LASIK eyes

- All available k-readings were used in Haigis formula, SRK/T formula, and SRK/T formula with double k modification.

- Haigis-L formula.

- Shammas modified IOLMaster k-reading was used in both Shammas-PL formula and double k modification of Holladay formula.
To calculate IOL power for post LASIK eyes

- IOL power was determined by a regression formula deduced from the results of the study.

- Different combinations of means of multiple IOL powers calculated using various formulas were hypothetically calculated.
• For the double-k modification of the third-generation formulas, an average k value of 43.86 D was used as the pre-refractive surgery k value.
The predictive accuracy of the calculation was analyzed by

- IOL prediction error = implanted IOL – calculated IOL power with the actual postoperative MRSE as a target refraction
- Refraction prediction error = actual MRSE – predicted MRSE

For each of them, the arithmetic mean (mean arithmetic error) and absolute mean (mean absolute error) were calculated.
The predictive accuracy of the calculation was analyzed by

In addition, percentages of correct refraction predictions within +/- 0.50 D, +/-1.00 D, and +/- 2.00 D were derived.
Statistical Analysis

• Comparisons of the means were performed with:
  – t test for paired samples.
  – ANOVA (Analysis Of Variance) test.

• Chi square and Fisher's exact tests were used to compare different frequencies.
Post-LASIK eyes

- 45 eyes of 37 patients.
  - Age: 51.27 ± 7.31 years (33 to 65 years).
- Sex:
  - Females: 26 (70%).
  - Males: 11 (30%).
Post-LASIK eyes

• Mean AL: 28.66 ± 2.78 mm
  – range 24.01 to 33.48 mm.
• Mean ACD: 3.43 ± 0.35 mm
  – range 2.74 to 4.86 mm.
## K-values of the included eyes

<table>
<thead>
<tr>
<th></th>
<th>Mean ±SD (D)</th>
<th>Range (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auto k</strong></td>
<td>37.31 ± 2.83</td>
<td>31.50 - 45.25</td>
</tr>
<tr>
<td><strong>Manual k</strong></td>
<td>37.58 ± 2.86</td>
<td>31.75 - 45.50</td>
</tr>
<tr>
<td><strong>IOLMaster k</strong></td>
<td><strong>37.06 ± 2.98</strong></td>
<td>31.25 - 44.94</td>
</tr>
<tr>
<td><strong>Pentacam</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sim k</td>
<td>36.55 ± 3.08</td>
<td>30.30 - 44.10</td>
</tr>
<tr>
<td>EKR 1 mm</td>
<td>34.37 ± 3.63</td>
<td>26.30 - 42.60</td>
</tr>
<tr>
<td>EKR 2 mm</td>
<td>34.72 ± 3.45</td>
<td>27.00 - 42.70</td>
</tr>
<tr>
<td>EKR 3 mm</td>
<td>35.35 ± 3.19</td>
<td>28.40 - 43.00</td>
</tr>
<tr>
<td>EKR 4 mm</td>
<td>36.22 ± 2.90</td>
<td>30.30 - 43.50</td>
</tr>
<tr>
<td>EKR 4.5 mm</td>
<td>36.73 ± 2.76</td>
<td>31.30 - 43.70</td>
</tr>
<tr>
<td>True net k</td>
<td>34.54 ± 3.15</td>
<td>27.70 - 41.90</td>
</tr>
</tbody>
</table>
Haigis formula using different k-values
Haigis formula using different k-values

<table>
<thead>
<tr>
<th></th>
<th>Eyes within $\pm$ 2 D Number (%)</th>
<th>Eyes within $\pm$ 1 D Number (%)</th>
<th>Eyes within $\pm$ 0.5 D Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EKR 3 mm</strong></td>
<td>43 (95.6)</td>
<td>34 (75.6)</td>
<td>16 (35.6)</td>
</tr>
<tr>
<td><strong>EKR 4 mm</strong></td>
<td>44 (97.8)</td>
<td>32 (71.1)</td>
<td>17 (37.8)</td>
</tr>
</tbody>
</table>

Arithmetic refractive error (D):

<table>
<thead>
<tr>
<th></th>
<th>EKR 3 mm</th>
<th>EKR 4 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EKR 3 mm</strong></td>
<td>-0.37 $\pm$ 0.88</td>
<td>0.46 $\pm$ 0.81</td>
</tr>
<tr>
<td><strong>EKR 4 mm</strong></td>
<td>(-2.44 to 1.90)</td>
<td>(-1.86 to 2.50)</td>
</tr>
</tbody>
</table>
SRK/T formula using different k-values
SRK/T formula using different k-values

<table>
<thead>
<tr>
<th></th>
<th>Eyes within ± 2 D Number (%)</th>
<th>Eyes within ± 1 D Number (%)</th>
<th>Eyes within ± 0.5 D Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>True net k</strong></td>
<td>45 (100.0)</td>
<td>32 (71.1)</td>
<td>14 (31.1)</td>
</tr>
</tbody>
</table>

**Arithmetic refractive error (D):**

\[
0.18 \pm 0.88 \\
(-1.90 to 1.67)
\]
SRK/T formula using different k-values

• The result of the present study with tru net k was inferior to that of Kim et al using the same formula.

<table>
<thead>
<tr>
<th></th>
<th>Kim et al(2009)</th>
<th>Present study</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 1 D</td>
<td>93 %</td>
<td>71.1%</td>
</tr>
<tr>
<td>± 0.5 D</td>
<td>70 %</td>
<td>31.1%</td>
</tr>
</tbody>
</table>

dk SRK/T formula using different k-values
**dk SRK/T formula using different k-values**

<table>
<thead>
<tr>
<th></th>
<th>within ± 2 D Number (%)</th>
<th>within ± 1 D Number (%)</th>
<th>within ± 0.5 D Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IOLMaster k</strong></td>
<td>41 (91.1)</td>
<td>27 (60.0)</td>
<td>13 (28.9)</td>
</tr>
<tr>
<td><strong>Pentacam</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sim k</strong></td>
<td>44 (97.8)</td>
<td>32 (71.1)</td>
<td>18 (40.0)</td>
</tr>
<tr>
<td><strong>EKR 4 mm</strong></td>
<td>44 (97.8)</td>
<td>36 (80.0)</td>
<td>19 (42.2)</td>
</tr>
<tr>
<td><strong>EKR 4.5 mm</strong></td>
<td>44 (97.8)</td>
<td>29 (64.4)</td>
<td>16 (35.6)</td>
</tr>
</tbody>
</table>

**Arithmetic refractive error (D)**

<table>
<thead>
<tr>
<th>EKR 4 mm</th>
<th>0.10 ± 0.79</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(-2.04 to 1.97)</td>
</tr>
</tbody>
</table>
Formulas using modified IOLMaster k-values

<table>
<thead>
<tr>
<th></th>
<th>Eyes within $\pm 2D$ Number (%)</th>
<th>Eyes within $\pm 1D$ Number (%)</th>
<th>Eyes within $\pm 0.5D$ Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Haigis-L</strong></td>
<td>41 (91.1)</td>
<td>33 (73.3)</td>
<td>20 (44.4)</td>
</tr>
<tr>
<td><strong>Shammas-PL</strong></td>
<td>45 (100.0)</td>
<td>38 (84.4)</td>
<td>26 (57.8)</td>
</tr>
<tr>
<td><strong>Shammas-dk</strong></td>
<td>43 (95.6)</td>
<td>37 (82.2)</td>
<td>25 (55.6)</td>
</tr>
<tr>
<td><strong>Holladay</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Formulas using modified IOLMaster k values

<table>
<thead>
<tr>
<th>Formula</th>
<th>Arithmetic refractive error (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
</tr>
<tr>
<td></td>
<td>(Range)</td>
</tr>
<tr>
<td>Haigis-L</td>
<td>-0.47 ± 0.90</td>
</tr>
<tr>
<td></td>
<td>(-2.79 to 1.62)</td>
</tr>
<tr>
<td>Shammas-PL</td>
<td>-0.24 ± 0.67</td>
</tr>
<tr>
<td></td>
<td>(-1.98 to 1.29)</td>
</tr>
<tr>
<td>Shammas-dk Holladay</td>
<td>-0.12 ± 0.80</td>
</tr>
<tr>
<td></td>
<td>(-1.64 to 2.26)</td>
</tr>
</tbody>
</table>
Formulas using modified IOLMaster k-values

- Shammas and Shammas showed the best results were with Shammas-PL formula.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean absolute IOL prediction error</td>
<td>0.55 ± 0.31 D</td>
<td>0.77 ± 0.65 D</td>
</tr>
<tr>
<td>Eyes within ± 1 D</td>
<td>93.3%</td>
<td>84.4%</td>
</tr>
</tbody>
</table>

Formulas using modified IOLMaster k-values

• Haigis published better results for Haigis-L formula in his series of 186 eyes.

<table>
<thead>
<tr>
<th></th>
<th>Haigis W (2008)</th>
<th>Present study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean arithmetic refraction prediction error</td>
<td>-0.04 ± 0.70 D</td>
<td>-0.47 ± 0.90 D</td>
</tr>
<tr>
<td></td>
<td>(-2.30 to 2.40 D)</td>
<td>(-2.79 to 1.62 D)</td>
</tr>
<tr>
<td>- Within ± 2 D</td>
<td>98.4%</td>
<td>91.1%</td>
</tr>
<tr>
<td>- Within ± 1 D</td>
<td>84.0%</td>
<td>73.3%</td>
</tr>
<tr>
<td>- Within ± 0.5 D</td>
<td>61.0%</td>
<td>44.4%</td>
</tr>
</tbody>
</table>

Regression formula

• IOL power =

\[ \text{(result of SRK/T formula using IOLMaster } k) + (0.181 \times \text{axial length}) - 2.151 \]
Regression formula

**Arithmetic refractive error (D)**

\[
\text{Mean} \pm \text{SD} \\
\text{(Range)}
\]

\[-0.02 \pm 0.87\]

\[-1.70 \text{ to } 1.60\]

“after excluding a case with -3.21”
From above, the best results were with:

- Haigis formula using EKR 4 mm.
- SRK/T formula using true net power.
- dk SRK/T formula using EKR 4 mm.
- Shammas-PL.
- Haigis-L.
- The deduced regression formula.
The best combinations of formulas were:

– "Shammas-PL + Haigis using EKR 4 mm".
– "Shammas-PL + Haigis using EKR 4 mm + Haigis-L".
– "Shammas-PL + dk SRK/T using EKR 4 mm".
– "Shammas-PL + dk SRK/T using EKR 4 mm + Haigis-L".
– "Shammas-PL + SRK/T using true net k".
Various combinations of formulas

- The five combinations yielded excellent results.
  - within $\pm 2$ D: 100%
  - within $\pm 1$ D: > 88%
  - within $\pm 0.5$ D: > 55%
Various combinations of formulas

<table>
<thead>
<tr>
<th>Arithmetic refractive error (D)</th>
<th>Shammas-PL + dk SRK/T EKR 4 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes within ± 2 D</td>
<td>-0.07 ± 0.56 (-1.04 to 1.30)</td>
</tr>
<tr>
<td>Eyes within ± 1 D</td>
<td>45 (100.0)</td>
</tr>
<tr>
<td>Eyes within ± 0.5 D</td>
<td>42 (93.3)</td>
</tr>
<tr>
<td></td>
<td>30 (66.7)</td>
</tr>
</tbody>
</table>
Clinical History method

- The pre-refractive surgery data (preoperative k and change in refraction) were available in five cases.

- No case was within \(+1\) D of intended refraction and only 2 out 5 cases were within \(+2\) D.
Subgroup Analysis

- Didn’t show statistically significant difference between both subgroups (with different implanted IOL material) except when using Haigis formula with EKR 3 mm.
<table>
<thead>
<tr>
<th>Formula / Method</th>
<th>within ± 2 D</th>
<th>within ± 1 D</th>
<th>within ± 0.5 D</th>
<th>Arithmetic refractive error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haigis using EKR 3 mm</td>
<td>(95.6)</td>
<td>(75.6)</td>
<td>(35.6)</td>
<td>-0.37 ± 0.88 (-2.44 to 1.90)</td>
</tr>
<tr>
<td>SRK/T true net k</td>
<td>(100.0)</td>
<td>(71.1)</td>
<td>(31.1)</td>
<td>0.18 ± 0.88 (-1.90 to 1.67)</td>
</tr>
<tr>
<td>dk SRK/T using sim k</td>
<td>(97.8)</td>
<td>(71.1)</td>
<td>(40)</td>
<td>0.44 ± 0.74 (-1.58 to 2.28)</td>
</tr>
<tr>
<td>dk SRK/T using EKR 4 mm</td>
<td>(97.8)</td>
<td>(80.0)</td>
<td>(42.2)</td>
<td>0.10 ± 0.79 (-2.04 to 1.97)</td>
</tr>
<tr>
<td>Shammas-PL</td>
<td>(100.0)</td>
<td>(84.4)</td>
<td>(57.8)</td>
<td>-0.24 ± 0.67 (-1.98 to 1.29)</td>
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<tr>
<td>Haigis-L</td>
<td>(91.1)</td>
<td>(73.3)</td>
<td>(44.4)</td>
<td>-0.47 ± 0.90 (-2.79 to 1.62)</td>
</tr>
<tr>
<td>Regression formula</td>
<td>(97.8)</td>
<td>(80.0)</td>
<td>(48.9)</td>
<td>-0.02 ± 0.87 (-3.21 to 1.60)</td>
</tr>
<tr>
<td>Shammas-PL + dk SRK/T using EKR 4 mm</td>
<td>(100.0)</td>
<td>(93.3)</td>
<td>(66.7)</td>
<td>-0.07 ± 0.56 (-1.04 to 1.30)</td>
</tr>
</tbody>
</table>
Conclusion

• Manual k & automated k readings were steeper than that measured by the IOLMaster
• Their use in IOL power calculation formulas after myopic LASIK would have left the patient in a more hyperopic condition.
Conclusion

• The use of Pentacam Scheimpflug imaging and Holladay equivalent k readings improved the accuracy of IOL power calculation after myopic LASIK.
Conclusion

• The use of means of combinations of formulas yielded excellent results better than any single formula alone for post-LASIK eyes.
Recommendations
For post-LASIK eyes

- When using IOLMaster alone:
  - Shammas-PL formula
  - The deduced regression formula
  - Haigis-L formula
For post-LASIK eyes

- When using Pentacam without Holladay report:
  - the combination of "Shammas-PL + SRK/T using true net k".

- When using Pentacam with Holladay report:
  - the combination of "Shammas-PL + dk SRK/T using EKR 4 mm".
Thank you