Correlation of Aberrometry, Contrast Sensitivity, and Subjective Symptoms With Quality of Vision After LASIK

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ABSTRACT

PURPOSE: To compare which parameter category (wavefront data, psychophysical data, or subjective symptoms) predicts best subjective quality of vision after LASIK.

METHODS: Twenty-eight eyes (15 patients) were included. Twenty-three eyes (12 patients) underwent uneventful LASIK; 5 eyes (3 patients) were symptomatic eyes treated with myopic LASIK elsewhere. Mean preoperative spherical equivalent refraction was $-4.79 \pm 1.92$ diopters (D) (range: $-1.63$ to $-7.13$ D); mean patient age was $36.6 \pm 7.4$ years (range: 18 to 48 years). All examinations were performed 1 month postoperatively. The wavefront error was described with Zernike polynomials (6-mm pupil). Psychophysical tests included high-contrast visual acuity and contrast sensitivity with and without glare at 167 cd/m$^2$, 1.67 cd/m$^2$, and high-contrast visual acuity and contrast sensitivity with nominal (6-mm pupil) psychophysical tests included high-contrast visual acuity and contrast sensitivity with and without glare at 167 cd/m$^2$, 1.67 cd/m$^2$, and 0.167 cd/m$^2$ with best spectacle correction. Correspondingly, overall subjective quality of vision and frequency of visual symptoms (glare, halos, starbursts, ghosting, blur) were assessed for three lighting conditions (photopic, high-mesopic, low-mesopic) using a questionnaire with a visual analog scale. For each parameter category and each lighting condition, a multiple stepwise backwards regression model with the overall quality of vision item value as dependent was applied.

RESULTS: Under all lighting conditions, subjective symptom scores predicted subjective quality of vision best (adjusted $R^2=0.83-0.92$) with blur as the main predictor throughout all conditions. Psychophysical tests did not significantly predict postoperative subjective quality of vision. The adjusted $R^2$ for the Zernike coefficients was highest for low-mesopic (0.56) and lowest for photopic conditions (0.31).

CONCLUSIONS: Different parameter categories for the description of optical quality did not predict subjective quality of vision after LASIK equally. Subjective symptom scores had the highest predictability, whereas psychophysical tests with spectacle correction had no predictability. The latter probably do not reflect all dimensions of subjective quality of vision.

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published.23-31 Although a multitude of publications address single aspects of subjective quality of vision in refractive surgery, the challenge of establishing connections between the different parameters remains. Compared to the plethora of descriptive reports, only a few authors investigated the correlation of either wavefront with functional data6,12,32-35 or functional with psychometric data,11,29-31,36 or wavefront with psychometric data.30,37-38

As a working hypothesis, our group has proposed a paradigm for “Quality of Vision.”39 On a basic level, anatomical features, such as characteristics of the corneal surface, corneal curvature, clearness of the optical media, and axial length of the eye, determine the quality of the retinal image. The quality of the retinal image influences basic visual tasks such as resolution and contrast detection. Finally, the image is processed by the visual system. This leads to a specific perception of the initial visual stimulus and to a final evaluation of the overall image quality by the viewer. For the operational definition of “subjective quality of vision,” the benchmark is the patient’s assessment of his/her quality of vision, because it is the patient who ultimately decides if his/her vision is “good” or “bad.” On the other hand, it is important to note that the anatomical level is the input level, as surgical interventions exclusively take place at this level with consecutive influence on the other levels.

The main objective of the present study is the comparison of the ability of different parameter categories to predict subjective quality of vision after LASIK. Subjective quality of vision after LASIK was assessed using a questionnaire, and regression analysis was applied to compare the predictive ability of questionnaire symptom scores (psychometric data), high-contrast visual acuity, contrast sensitivity, and disability glare (psychophysical data) and Zernike coefficients (wavefront data).

**PATIENTS AND METHODS**

**PATIENT SELECTION**

Twenty-eight eyes of 15 patients who underwent LASIK for myopia were included in this study. Twenty-three eyes of 12 patients were selected from a larger cohort described elsewhere.40 Those patients were treated with wavefront-guided LASIK using a static rotation-sensitive eye tracker with iris recognition (Zyoptix; Bausch & Lomb, Rochester, NY). Additionally, 5 symptomatic postoperative LASIK eyes of 3 patients were included. These patients had received LASIK for myopia elsewhere and presented at our institution for a topography-guided retreatment. This subgroup was included to obtain a larger range of subjective quality of vision data, containing patients both satisfied and dissatisfied with their subjective quality of vision. Demographic and clinical data are shown in Table 1. Beyond the indication for myopic wavefront-guided LASIK aiming at emmetropia or topography-guided LASIK retreatment, inclusion criteria were consent and ability to participate at additional examinations for study purposes. Patients with previous ocular disease potentially interfering with visual function, anatomical anomalies that most likely affect optical quality (eg, dry eye, flap striae, or haze), psychiatric conditions, and those unable to speak German or English were not included. As described elsewhere,19,40 a comprehensive clinical examination was performed preoperatively to reveal potential contraindications for myopic LASIK or topography-guided LASIK retreatment.

For study purposes, patients received a questionnaire on subjective quality of vision and underwent additional psychophysical testing and aberrometry pre- and postoperatively. For this study, only the results obtained 1 month postoperatively in the wavefront-guided LASIK group and prior to retreatment in the symptomatic group were analyzed. For all study procedures, the tenets of the Declaration of Helsinki were followed. All patients were informed about the surgical procedure and the nature of the study and gave written consent.

**SURGICAL TREATMENT**

For preparation of wavefront-guided LASIK, aberrometry was performed with a Hartmann-Shack wavefront sensor (Zywave; Bausch & Lomb/Technolas, Munich, Germany) in maximum mydriasis. The median programmed optical zone diameter was 6.5 mm (range: 6.0 to 7.0 mm) (Table 1). Optical zone diameters were based on the mesopic pupil diameter, measured at 0.4 lux (Procyon infrared pupillometer; Procyon Instruments Ltd/Haag-Streit UK, Harrow, United Kingdom), the expected ablation depth provided by the laser software, and corneal pachymetry measured with an ultrasound pachymeter (SP-3000; Tomey, Erlangen, Germany). The Hansatome microkeratome (Zyoptix XP, Bausch & Lomb) with the 160-µm head and 9.5-mm ring was used in all cases. Tissue ablation was performed with the Technolas 217z excimer laser (Bausch & Lomb/Technolas) using a wavefront-guided ablation algorithm (Zyoptix, version 3.21). Postoperative standard medication consisted of ofloxacin eye drops (Floxal; Dr Mann/Bausch & Lomb, Berlin, Germany) and fluorometholone eye drops (Efflumidex; Pharm-Allergan, Ettlingen, Germany). Artificial tears...
(Cellufresh; Pharm-Allergan) were also prescribed. No patient in the wavefront-guided LASIK subgroup experienced intra- or postoperative complications. Routine controls were scheduled for 1 day, 1 week, and 1 month postoperatively.

**Postoperative Wavefront Analysis**

Wavefront sensing for study purposes was performed in maximal mydriasis using the Zywave aberrometer. Wavefront errors were reconstructed over a 6.0-mm pupil diameter using Zernike polynomials from the second to the fifth order following the Visual Science and Its Application (VSIA) standards for reporting aberration data of the eye. For simplification, root-mean-square (RMS) values were calculated for lower order aberrations, total higher order aberrations, all third- and fifth-order coma terms (coma RMS, the RMS of $C^{3 \times 3}$), spherical aberration, and all non-coma, non-spherical Zernike modes (residual higher order aberrations RMS, the RMS of $C^{3 \times 3}$).

**Psychophysical Tests: High-Contrast Visual Acuity, Contrast Sensitivity, and Disability Glare**

All psychophysical tests of this study were performed in the same testing laboratory under standardized lighting conditions. Daylight was blocked and the ambient illumination was adapted to the luminance conditions of each test by indirect room lights. Luminance and illumination were measured with a luminance meter (LS-100; Konica Minolta, Osaka, Japan) and illuminance meter (Illuminance Meter; Konica Minolta), respectively. Both high-contrast visual acuity and contrast sensitivity were tested monocularly with best spectacle correction (trial frame; Oculus Optikgeräte, Wetzlar, Germany) and physiological (undilated) pupils.

High-contrast visual acuity and contrast sensitivity were measured using the Frankfurt-Freiburg Contrast and Acuity Test System (FF-CATS). The FF-CATS is a test based on the Freiburg Visual Acuity and Contrast Test (FrACT) and has been described in detail elsewhere. Briefly, it is a computerized test for the determination of acuity and contrast thresholds and disability glare under different luminance conditions. The best parameter estimation by sequential testing (PEST) algorithm in combination with an eight-alternative, forced-choice procedure provides observer-independent measurements with a low probability of guessing.

For visual acuity testing, high-contrast Landolt C rings were displayed on a high-resolution, black-and-white monitor with a background luminance of 270 cd/m² for photopic conditions. For contrast sensitivity and disability glare testing, Landolt rings of constant size (1.3 logMAR, according to the letter size of the Pelli-Robson Test) were presented; photopic background luminance was 167 cd/m². Eight white light emitting diodes, displaced at an angle of 3.2° from the center of the ring, acted as glare sources with an illuminance of 0.32 lux. For mesopic testing, monitor luminance was reduced by neutral density filters ($\tau = 10^{-2}$ for high-mesopic luminance and $\tau = 10^{-3}$ for low-mesopic luminance). This resulted in corresponding luminance levels of 2.7 cd/m² and 1.67 cd/m² (high-mesopic conditions) and 0.27 cd/m² and 0.167 cd/m² (low-mesopic conditions).

In total, three high-contrast visual acuity measurements, three contrast sensitivity measurements without glare, and three contrast sensitivity measurements with glare were performed per eye. Disability glare scores reflect the change of contrast sensitivity due to glare; they were calculated by subtracting contrast sensitivity values obtained without glare from those obtained with glare. The positions of the perceived gap of the Landolt C were typed into the computer with a key pad by the patient. Patients did not receive any feedback on the correctness of each response, and the observer did not interfere with the testing.

**Questionnaire**

Patients were asked to estimate the frequency of visual symptoms and their overall subjective optical quality on a six-item questionnaire with a visual analog scale (range: 0 to 100 points). The selection of items on the questionnaire is based on those visual symptoms of which patients complained most frequently in our refractive surgical practice. To achieve a more robust correlation with other parameters, each question had to be answered separately for the right and left eye and for three different luminance conditions, which were referred to as “...bright light, eg, in sunlight, outdoors or under optimal workplace illumination” (photopic conditions), “...‘normal light’ (intermediate brightness), eg, at your workplace or indoors” (high-mesopic conditions), and “...in dim light, eg, in twilight or at night” (low-mesopic conditions). Item collapsing and repeatability analysis were not performed. Five of the six questions addressed the frequency of the visual symptoms “glare,” “halos,” “starbursts,” “blurry or fuzzy vision,” and “ghost images” with “never” crediting 0 and “always” 100 points. The sixth question asked the patient to judge his or her “...overall optical quality...” The two extremes for the overall subjective quality of vision item were “perfect” (0 points) and “extremely bad” (100 points). Before patients answered the questions, the characteristics of the different symptoms and the concept of “quality of vision” was ex-
explained comprehensively to each patient both orally and by the instruction sheet attached to the questionnaire. The latter should forestall false judgment by the patients, eg, mistakenly considering contact lens wear discomfort or dry eye problems relevant for subjective quality of vision. Point scores from the visual analog scale were read using a ruler.

OUTCOME MEASURES AND STATISTICS

Main outcome measures were:
1. Subjective (psychometric) parameters: postoperative overall subjective quality of vision and symptom scores from the questionnaire, obtained separately for right and left eyes and for three lighting conditions (photopic, high-mesopic, and low-mesopic).
2. Functional (psychophysical) parameters: postoperative high-contrast visual acuity, contrast sensitivity, and disability glare measured under three lighting conditions (photopic, high-mesopic, and low-mesopic).
3. Wavefront parameters: postoperative wavefront aberrations, expressed as Zernike coefficients over a 6-mm pupil diameter. Because individual Zernike coefficients proved to be the wavefront error representation that predicted the variance of postoperative subjective quality of vision best in a previous study,38 we chose individual coefficients rather than RMS values or optical quality metrics as predictors in the model.

A multiple stepwise backward regression model was applied to investigate the ability of each parameter category (subjective, functional, and wavefront) to predict subjective quality of vision. Thus, the overall subjective quality of vision score was the dependent in the model, whereas the parameters of each category were the predictors. For each parameter category and for each lighting condition, a separate model was computed. Partial raw (B) and standardized regression coefficients (β) and P values for each factor included in the model were calculated. In a subsequent procedure, variables with P>0.05 (based on the F value) were eliminated from the model step-by-step to uncover the factors with statistically significant impact on subjective quality of vision. For final analysis, B and β values of factors of significant influence and multiple coefficients of determination (multiple R2 adjusted for sample size and number of independents) were compared after non-significant values were eliminated from the model. All statistical analyses were performed using SPSS 11.0 (SPSS Inc, Chicago, Ill).

RESULTS

DEMOGRAPHICS AND GENERAL RESULTS

The median postoperative spherical equivalent was −0.50 diopters (D). Further demographic and clinical data including the preoperative refraction are shown in Table 1.

QUESTIONNAIRE: OVERALL SUBJECTIVE OPTICAL QUALITY AND SYMPTOMS

The median postoperative optical quality was 17 under photopic, 20 under high-mesopic, and 30 under low-mesopic lighting conditions (Table 2, Fig 1A).
Quality of Vision After LASIK/Bühren et al

Functional Tests: High-Contrast Visual Acuity, Contrast Sensitivity, and Disability Glare

Results of psychophysical tests as obtained with best spectacle correction under three lighting conditions with the FF-CATS are shown in Table 4 and Figure 2. Throughout all parameters tested, patients obtained highest visual acuity and contrast sensitivity scores and lowest disability glare scores under photopic conditions, followed by high- and low-mesopic conditions with an almost constant range between minimum and maximum data (Table 4) (see Fig 2).

Wavefront Data: RMS Values and Zernike Coefficients

Median postoperative lower order aberration RMS, computed for a pupil diameter of 6 mm, was 1.072 µm; higher order aberration RMS was 0.608 µm. Higher order aberrations were dominated by positive C4 (0.375 µm) in all eyes followed by coma RMS and RMS of the residual Zernike terms (Table 5). Figure 3 shows the breakdown into single Zernike coefficients, which were used as predictors in one of the multiple regression models.

Multiple Regression Analysis

Subjective symptom scores were the parameters that predicted subjective quality of vision best. For all lighting conditions, adjusted coefficients of determination (R²) were similar and ranged between 0.83 and 0.92 (Table 6). The symptom “blur” was present in the models throughout all lighting conditions and had the
highest $\beta$ values and lowest $P$ values ($P<.001$) in all models. Besides blur, ghosting played a role for photopic and glare and halos for low-mesopic subjective quality of vision. However, $\beta$ values for the latter items were lower than those for the blur items (Table 6).

Psychophysical test scores had the poorest predictability for subjective quality of vision. No functional tests (high-contrast visual acuity, contrast sensitivity, and disability glare) were able to predict subjective quality of vision significantly (adjusted $R^2=0$).

Zernike coefficients had a variable ability to predict subjective quality of vision, depending on the lighting conditions tested. Highest predictability was found under low-mesopic conditions (adjusted $R^2=0.56$; Table 6). Coefficients included two lower order aberration coefficients ($C_{20}^2$, $C_{22}^2$), both third-order coma terms, and three fifth-order terms. The quantitative influence of the seven coefficients in the model varied as the magnitude of $\beta$ ranged between 0.32 ($C_{20}^2$, $P=.031$) and 0.97 ($C_{55}^2$, $P<.001$). For low-mesopic conditions, adjusted $R^2$ was 0.45. Besides oblique astigmatism ($C_{21}^2$) and vertical coma ($C_{13}^1$), both secondary trefoil terms remained in the model with highest impact of $C_{-3}^5$ ($\beta=0.73$, $P=.002$) on low-mesopic subjective quality of vision. Zernike coefficients had the lowest predictability on photopic subjective quality of vision (adjusted $R^2=0.31$) with two coefficients ($C_{42}^2$ and $C_{55}^2$) remaining in the model.

**DISCUSSION**

Although based on a small patient population, this study is—to our knowledge—the first to compare the ability of different parameter categories to predict subjective quality of vision after LASIK. The core finding of the present study is that substantial differences exist between the ability of symptom scores, psychophysical measurements, and wavefront data to predict subjective quality of vision, with a surprisingly poor performance of visual acuity, contrast sensitivity, and disability glare scores.

Subjective symptom scores predicted between 83%
(photopic conditions) and 92% (high-mesopic conditions) of the variance of the subjective quality of vision score (Table 6). Throughout all lighting conditions, the blur item had the highest impact in the regression model. Together with the presence of second-order aberrations in the model based on wavefront data (Table 6) and our previous study, this underlines the important role of residual refractive error for postoperative LASIK subjective quality of vision. Beyond blur ghosting (photopic conditions), the effect that glare and halos (low-mesopic conditions) have on subjective quality of vision appears obvious: ghost images are a phenomenon of higher spatial frequencies, which require an object of high contrast. This corresponds to reading situations in bright light in everyday life. Conversely, glare and halos require a more or less point-shaped light source and a background of relative dark color to be noticed; typically, this is the case under low light conditions. The high predictive ability of subjective symptom scores could be explained by the fact that subjective quality of vision and symptom scores were obtained with the same method and have similar dimensions. Both values are subjective and, in our hypothetical sequence for definition of quality of vision, the symptom scores are closest to the overall subjective quality of vision item. Furthermore, the results show that the choice of symptom items appears to be valid.

With regard to the widespread use, the poor predictive ability of psychophysical test data is somewhat alarming. The foremost reason for the low correlation with subjective quality of vision scores is the fact that all functional tests were performed with best spectacle correction; however, none of the patients used a habitual spectacle correction postoperatively. Although testing contrast sensitivity with best correction is a common practice, measuring best spectacle-corrected visual acuity alone turned out to be insufficient. This could be explained by the strong influence of residual refractive error (second-order aberrations, Table 6) and is also reflected by the dominance of the blur item.

This confirms recent results of uncorrected visual acuity being predictive for patient satisfaction using the National Eye Institute RQL instrument. It appears likely that for a comprehensive functional evaluation, the tests should be performed with the patient’s habitual correction, ie, uncorrected if the patient does not use any form of correction. In the present patient collective, compensating for residual refractive error by spectacle correction did not leave any higher order aberration-induced functional deficits that could be uncovered with the test used. This raises the question whether the test target for contrast sensitivity testing should be changed from the large size of 1.3 logMAR to a smaller optotype as suggested by Rabin and Wicks. A small optotype target might be more sensitive to aberration-induced blur, especially if phase reversals are involved. Moreover, the Landolt C is likely to be advantageous over sine wave gratings, as the gap is presented in eight different directions and a potential
influence of a preferential orientation\textsuperscript{49} of the grating is reduced to a minimum. Another potential cause for the poor performance is a flawed test; however, the FF-CATS fulfills the requirements for psychophysical tests,\textsuperscript{46,50} has been evaluated thoroughly before, and proved to produce valid results with a reasonable repeatability.\textsuperscript{43,44} Further studies are necessary to optimize the conditions and test conditions and procedures for quality of vision evaluation with psychophysical tests. This is of particular importance because extensive test sequences involving different conditions (correction status, luminance, glare) could be exhausting for the patient and lead to wrong results due to fatigue.

One major advantage of aberrometry is the simplicity and objectivity of measurements. In the multivariate model, Zernike coefficients had a moderate predictability, which increased from photopic (adjusted $R^2=0.31$) over high-mesopic (adjusted $R^2=0.45$) to low-mesopic conditions (adjusted $R^2=0.56$), suggesting an increasing influence of wave aberrations with pupil diameter. As in our previous study,\textsuperscript{38} second- and fifth-order aberrations had a significant impact on subjective quality of vision. Although the role of second-order aberrations is obvious and has also been suggested by others,\textsuperscript{47} the impact of fifth-order aberrations does not seem clear. Although positive spherical aberration ($C_4^2$) was the dominant aberration (Table 5; see Fig 3C), it is likely that it is present in eyes with both good and bad subjective quality of vision whereas the amount of concomitant fifth-order aberration distinguishes symptomatic from asymptomatic eyes. It remains to be determined whether the calculation of wavefront errors over the individual pupil diameter at a given lighting condition could increase the correlation of wavefront

### TABLE 6

<table>
<thead>
<tr>
<th>Lighting Condition</th>
<th>R$^2$ (Adjusted)</th>
<th>Predictors</th>
<th>B</th>
<th>$\beta$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjective Symptom Scores</td>
<td></td>
<td>Blur</td>
<td>0.55</td>
<td>0.75</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ghosting</td>
<td>0.27</td>
<td>0.32</td>
<td>.001</td>
</tr>
<tr>
<td>Photopic</td>
<td>0.83</td>
<td>Blur</td>
<td>0.86</td>
<td>0.96</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>High-mesopic</td>
<td>0.92</td>
<td>Blur</td>
<td>0.32</td>
<td>0.29</td>
<td>.004</td>
</tr>
<tr>
<td>Low-mesopic</td>
<td>0.87</td>
<td>Glare</td>
<td>0.25</td>
<td>0.27</td>
<td>.004</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blur</td>
<td>0.51</td>
<td>0.53</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Psychophysical Test Data (Visual Acuity and Contrast Sensitivity)

No predictors left in the models under all three lighting conditions

Wavefront Data (Zernike Coefficients)

<table>
<thead>
<tr>
<th>Lighting Condition</th>
<th>R$^2$ (Adjusted)</th>
<th>$C_{2}^{2}$</th>
<th>$\beta$</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photopic</td>
<td>0.31</td>
<td>$-113.4$</td>
<td>$-0.59$</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$134.9$</td>
<td>$0.36$</td>
<td>.041</td>
</tr>
<tr>
<td>High-mesopic</td>
<td>0.45</td>
<td>$-28.0$</td>
<td>$-0.37$</td>
<td>.026</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$32.8$</td>
<td>$0.41$</td>
<td>.023</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$286.9$</td>
<td>$0.64$</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$571.5$</td>
<td>$0.73$</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-350.0$</td>
<td>$-0.50$</td>
<td>.004</td>
</tr>
<tr>
<td>Low-mesopic</td>
<td>0.56</td>
<td>$-13.2$</td>
<td>$-0.51$</td>
<td>.013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-54.7$</td>
<td>$-0.62$</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$70.5$</td>
<td>$0.76$</td>
<td>&lt;.001</td>
</tr>
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<td></td>
<td></td>
<td>$-50.2$</td>
<td>$-0.40$</td>
<td>.016</td>
</tr>
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<td></td>
<td></td>
<td>$294.5$</td>
<td>$0.56$</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$889.4$</td>
<td>$0.97$</td>
<td>&lt;.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$-266.3$</td>
<td>$-0.32$</td>
<td>.031</td>
</tr>
</tbody>
</table>

$R^2 = $ coefficient of determination, adjusted for sample size, $B =$ non-standardized partial regression coefficient, $\beta =$ standardized partial regression coefficient
data with subjective quality of vision. A study addressing this question is currently underway.

Although the results of this study are consistent, there are some limitations. First, the sample size is low. The main purpose of the present study was a cross-sectional exploration to build hypotheses rather than a longitudinal investigation of quality of vision after LASIK. Therefore, symptomatic eyes were included, which led to an asymmetric distribution of symptom strength (see Figs 1A-1F). In addition, in a cross-sectional sample examined with the National Eye Institute RQL questionnaire, scores were highly skewed towards satisfaction.47 It should be noted that in the case of separate analysis of a larger group of highly symptomatic patients, the predictive value of some of the parameters could have been higher. Second, only LASIK eyes were investigated. These patients were chosen because LASIK is the most common refractive surgical procedure.

This study showed that subjective quality of vision after LASIK is strongly influenced by subjective symptoms with lower order aberration blur being the most common reason for a low subjective quality of vision. Other symptoms were dependent on the lighting condition with a significant influence of fifth-order aberrations. Despite using a validated test under standardized conditions, the results from psychophysical tests obtained with best spectacle correction did not predict subjective quality of vision.

AUTHOR CONTRIBUTIONS
Study concept and design (J.B., T.K.); data collection (J.B., A.K.); interpretation and analysis of data (J.B., T.M., T.K.); drafting of the manuscript (J.B.); critical revision of the manuscript (J.B., T.M., A.K., T.K.); statistical expertise (J.B., T.M., T.K.); administrative, technical, or material support (A.K., T.K.); supervision (T.K.)

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