Comparison of LASIK With the OPDCAT or OATz Algorithm Using the NIDEK EC-5000CXII Excimer Laser

Yoshiko Hori-Komai, MD; Ikuko Toda, MD; Takahiro Yamamoto, MD; Kazuo Tsubota, MD

ABSTRACT

PURPOSE: To compare refractive outcomes, higher order aberrations, visual quality, and patient satisfaction between aspheric and whole-eye wavefront aspheric LASIK algorithms.

METHODS: Two hundred seventy-four eyes of 152 patients undergoing LASIK for myopia and myopic astigmatism were divided into two groups: eyes that underwent treatment using either the OPD-guided customized aspheric treatment (OPDCAT) or optimized aspheric treatment zone (OATz). Both groups were subdivided into two groups based on preoperative manifest refraction spherical equivalent (MRSE) ≤ 6.00 diopters (D) and eyes with MRSE ≥ −6.00 D. Both groups were additionally subdivided into eyes with preoperative ocular higher order aberrations ≤0.40 µm and eyes with higher order aberrations ≥0.40 µm. A P value <.05 was considered statistically significant.

RESULTS: At 3 months postoperatively, 88.3% (242/274) of eyes were available for follow-up. Postoperatively, 91.4% of eyes in the OPDCAT group and 90.6% of eyes in the OATz group were within 0.50 D. No difference in refractive outcomes and patient satisfaction among groups or subgroups was noted (P > .05). A significantly less change in asphericity (less oblate) was noted for the OPDCAT group (0.31 ± 0.30) compared with the OATz group (0.51 ± 0.35) (P < .05). A lower induction of aberrations in the OPDCAT group compared with the OATz group was noted (P < .05). Mesopic contrast sensitivity was significantly higher for the OPDCAT groups and subgroups (P < .05).

CONCLUSIONS: Refractive outcomes between groups or subgroups were equivalent. A significantly lower induction of higher order aberrations and less change in asphericity in the OPDCAT group was noted. The OPDCAT algorithm was more likely to maintain mesopic contrast sensitivity. [J Refract Surg. 2010;26(6):411-422.] doi:10.3928/1081597X-20090617-14

The safety and efficacy of wavefront-guided and aspheric LASIK has been well established. Studies on the refractive outcomes of wavefront-guided LASIK have shown it to be effective for the treatment of low to moderate myopia with astigmatism. The refractive outcomes of aspheric algorithms that do not incorporate the treatment of ocular wavefront aberrations have been equivalent to those reported for wavefront-guided LASIK. The potential benefit of each of these algorithms over conventional ablation algorithms is the reduced induction of aberrations, which maintains visual quality.

The advent of wavefront-guided ablations, wavefront-optimized ablations, aspheric ablations, and topography-guided ablations has led to confusion regarding the clinical application and benefit of each of these ablation algorithms compared with the other. For example, one study reported that aspheric ablations are adequate for the majority of patients whereas another found that topography-guided treatments are superior to aspheric or wavefront-guided treatments. Yet, other reports indicate that wavefront-guided treatments yield the greatest benefits for patients with greater than average higher order aberrations and that one should proceed with caution for patients with moderate or high myopia and large pupils. A relative paucity of studies compare aspheric LASIK for myopia with astigmatism to wavefront-guided LASIK.

This study presents the comparison of LASIK for the treatment of primary myopia with astigmatism using either the optimized aspheric treatment zone algorithm (OATz) or the OPD-guided customized aspheric treatment algorithm.
(OPDCAT) and investigates the differences in refractive outcomes, changes in wavefront aberrations, and objective and subjective visual quality postoperatively. The OPDCAT algorithm delivers an aspheric ablation to the full ablation diameter on the cornea and treats ocular higher order aberrations. The OATz algorithm delivers a wide aspheric transition zone only and does not incorporate the treatment of corneal or ocular higher order aberrations.

**PATIENTS AND METHODS**

**STUDY POPULATION AND EXAMINATIONS**

This retrospective study evaluated 274 eyes of 152 patients who underwent LASIK for myopia and myopic astigmatism using either the OATz or OPDCAT ablation algorithms with the NIDEK Advanced Vision Excimer Laser System (NAVEX; NIDEK Co Ltd, Gamura, Japan). Patients were selected using retrospective chart review specifically targeting eyes that underwent OATz or OPDCAT over separate 3-month periods. Patient inclusion criteria were age 20 to 60 years, preoperative best spectacle-corrected visual acuity (BSCVA) 1.0 (decimal notation) or better, manifest refraction spherical equivalent (MRSE) $\leq -10.00$ dioptrers (D) with sphere $\leq -9.00$ D and cylinder $\leq -3.00$ D, LASIK with 4.5-mm optical zone and 8.0-mm transition zone with profile #6, and 3-month postoperative data. Age, sex, average targeted correction, and pupil size for the measurement of aberrations were matched between groups. One hundred twenty-five eyes of 65 patients underwent LASIK with OPDCAT (OPDCAT group). One hundred forty-nine eyes of 87 patients underwent LASIK with OATz (OATz group). Both the OPDCAT and OATz groups were further subdivided based on preoperative refractive error classified as low for eyes with $<-6.00$ D MRSE (low MRSE group) and high for eyes with preoperative MRSE $\geq -6.00$ D (high MRSE group). Both the OPDCAT and OATz groups were further subdivided based on the magnitude of the preoperative ocular higher order aberration root-mean-square (RMS) value classified as low RMS for eyes with preoperative higher order aberration RMS $<0.40$ µm (low higher order aberration group) and high RMS for eyes with preoperative higher order aberration RMS $\geq 0.40$ µm (high higher order aberration group).

Patients who suffered from an acute illness, had previous corneal surgery, a calculated postoperative corneal bed thickness $<250$ µm after ablation, preoperative central corneal thickness $<475$ µm, previous ophthalmic surgery, or had abnormal corneal topography were excluded from the study. All patients signed an informed consent form approved by an independent review committee consistent with the tenets of the Declaration of Helsinki.

Preoperative ophthalmic examination included corneal topography, dark-adapted pupillometry and aberrometry (6-mm pupil) using the OPD-Scan (NIDEK Co Ltd), distance uncorrected visual acuity (UCVA) in decimal notation, BSCVA in decimal notation, MRSE, slit-lamp examination, tonometry, ultrasound pachymetry, and a dilated fundus examination. The same measurements (with the exception of dilated funduscopy and pupillometry unless warranted) were performed at 1 week and 1 and 3 months postoperatively. Mesopic contrast sensitivity was assessed preoperatively and 3 months postoperatively (CGT-1000; Takagi Seiko Co Ltd, Nagano, Japan). The subjective quality of vision was assessed preoperatively and 3 months postoperatively using a previously published questionnaire in which patients were requested to subjectively score their vision at night on a scale of 0 to 2 (easy to difficult) and their level of satisfaction with the outcome of the procedure on a scale of 1 to 4 (very satisfied to unsatisfied).

**TREATMENT SIMULATIONS AND DATA PREPARATION**

Prior to treatment simulations, the OPD-Scan maps were examined by an experienced clinician (Y.H., I.T., or T.Y.) to ensure adequate pupil coverage of at least 6 mm and that they were free of measurement artifacts. All treatments were simulated and the shot data were prepared using the Final Fit (NIDEK Co Ltd) ablation planning software. Various parameters, including optical zone, transition zone, laser profile, and amount of irregularity treatment, were entered to determine an adequate postoperative simulation map. A satisfactory simulated result was one for which the target simulated corneal topography minimized the gradient of corneal curvature change, maximized the effective optical zone yet maintained adequate residual corneal tissue, and reduced or eliminated ocular irregularities. After the treatment parameters were finalized, a simulation of postoperative corneal topography was generated and the shot data were exported to the NIDEK EC-5000CXII excimer laser.

For the OATz treatment simulation, Final Fit software was used based on corneal topography data obtained from the OPD-Scan, manifest refraction data
## TABLE 1
Preoperative Visual Acuity, Manifest Refraction Spherical Equivalent, Ocular Higher Order Aberrations, and Corneal Asphericity of Eyes That Underwent LASIK Using the NIDEK Advanced Vision Excimer Laser System

<table>
<thead>
<tr>
<th>Cohort</th>
<th>UCVA (logMAR)</th>
<th>BSCVA (logMAR)</th>
<th>MRSE (D)</th>
<th>Total HOA RMS (µm)</th>
<th>Spherical Aberration RMS (µm)</th>
<th>Coma Aberration RMS (µm)</th>
<th>Coma Asphericity</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPDCAT (n=125)</td>
<td>1.20±0.25 (0.40 to 1.70)</td>
<td>−0.16±0.05 (−0.20 to 0.00)</td>
<td>−5.42±2.02 (−10.00 to −1.75)</td>
<td>0.41±0.11 (0.18 to 0.72)</td>
<td>0.20±0.07* (0.09 to 0.37)</td>
<td>0.35±0.12 (0.17 to 0.71)</td>
<td>−0.20±0.15 (−0.63 to 0.11)</td>
</tr>
<tr>
<td>OATz (n=149)</td>
<td>1.18±0.24 (0.30 to 1.70)</td>
<td>−0.16±0.04 (−0.20 to 0.00)</td>
<td>−5.25±1.66 (−9.38 to −2.00)</td>
<td>0.39±0.11 (0.16 to 0.76)</td>
<td>0.18±0.06* (0.08 to 0.41)</td>
<td>0.33±0.12 (0.11 to 0.72)</td>
<td>−0.20±0.14 (−0.51 to 0.12)</td>
</tr>
<tr>
<td>OPDCAT &lt;−6.00 D (n=76)</td>
<td>1.08±0.21 (0.40 to 1.40)</td>
<td>−0.16±0.04 (−0.20 to 0.00)</td>
<td>−4.08±1.16 (−5.88 to −1.75)</td>
<td>0.41±0.11 (0.18 to 0.72)</td>
<td>0.18±0.06 (0.08 to 0.31)</td>
<td>0.36±0.11 (0.14 to 0.71)</td>
<td>−0.20±0.16 (−0.63 to 0.10)</td>
</tr>
<tr>
<td>OATz &lt;−6.00 D (n=96)</td>
<td>1.09±0.24 (0.30 to 1.5)</td>
<td>−0.16±0.04 (−0.20 to 0.00)</td>
<td>−4.22±0.97 (−5.89 to −2.00)</td>
<td>0.38±0.11 (0.17 to 0.61)</td>
<td>0.17±0.05 (0.06 to 0.35)</td>
<td>0.33±0.11 (0.11 to 0.58)</td>
<td>−0.19±0.13 (−0.51 to 0.11)</td>
</tr>
<tr>
<td>OPDCAT ≥−6.00 D (n=49)</td>
<td>1.38±0.17 (0.70 to 1.70)</td>
<td>−0.15±0.05 (−0.20 to 0.00)</td>
<td>−7.50±1.07† (−10.00 to −6.00)</td>
<td>0.41±0.11 (0.23 to 0.70)</td>
<td>0.21±0.08 (0.09 to 0.37)</td>
<td>0.34±0.12 (0.13 to 0.66)</td>
<td>0.41±0.13 (−0.41 to 0.11)</td>
</tr>
<tr>
<td>OATz ≥−6.00 D (n=53)</td>
<td>1.35±0.12 (1.10 to 1.70)</td>
<td>−0.16±0.04 (−0.20 to −0.10)</td>
<td>−7.11±0.81† (−9.38 to −6.00)</td>
<td>0.39±0.13 (0.16 to 0.76)</td>
<td>0.19±0.08 (0.09 to 0.41)</td>
<td>0.34±0.12 (0.13 to 0.72)</td>
<td>−0.21±0.15 (−0.45 to 0.12)</td>
</tr>
<tr>
<td>OPDCAT HOA RMS &lt;0.4 µm (n=55)</td>
<td>1.22±0.21 (0.50 to 1.50)</td>
<td>−0.17±0.03 (−0.20 to 0.00)</td>
<td>−5.20±1.75 (−9.75 to −2.38)</td>
<td>0.33±0.05† (0.18 to 0.40)</td>
<td>0.17±0.06 (0.08 to 0.31)</td>
<td>0.27±0.06 (0.13 to 0.38)</td>
<td>−0.20±0.14 (−0.57 to 0.11)</td>
</tr>
<tr>
<td>OATz HOA RMS &lt;0.4 µm (n=81)</td>
<td>1.21±0.25 (0.50 to 1.70)</td>
<td>−0.16±0.04 (−0.20 to 0.00)</td>
<td>−5.33±1.83 (−9.38 to −2.00)</td>
<td>0.30±0.06† (0.16 to 0.40)</td>
<td>0.16±0.05 (0.06 to 0.35)</td>
<td>0.25±0.07 (0.11 to 0.38)</td>
<td>−0.21±0.14 (−0.51 to 0.07)</td>
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<td>OPDCAT HOA RMS ≥0.4 µm (n=58)</td>
<td>1.21±0.25 (0.50 to 1.70)</td>
<td>−0.15±0.06 (−0.20 to 0.00)</td>
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<td>0.22±0.07 (0.09 to 0.37)</td>
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</tr>
<tr>
<td>OATz HOA RMS ≥0.4 µm (n=63)</td>
<td>1.15±0.23 (0.30 to 1.50)</td>
<td>−0.16±0.04 (−0.20 to 0.00)</td>
<td>−5.17±1.41 (−8.00 to −2.13)</td>
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<td>−0.18±0.14 (−0.45 to 0.12)</td>
</tr>
</tbody>
</table>

UCVA = uncorrected visual acuity, BSCVA = best spectacle-corrected visual acuity, MRSE = manifest refraction spherical equivalent, HOA RMS = higher order aberration root-mean-square, OPDCAT = OPD-guided customized aspheric treatment algorithm, OATz = optimized aspheric treatment zone algorithm

*Denotes statistically significant difference in spherical aberration between the OPDCAT and OATz groups (P=.030).
†Denotes statistically significant difference in MRSE between the OPDCAT and OATz subgroups with ≥−6.00 D MRSE (P=.042).
‡Denotes statistically significant difference in total HOA RMS values between the OPDCAT and OATz subgroups with <0.4 µm HOA RMS (P=.014).
entered manually, or the objective refraction data obtained from the OPD-Scan to simulate postoperative corneal shape and generate shot data for treatment. The programmed optical zone was 4.5 mm and programmed transition zone was 8.0 mm with profile #610 and were used for all OATz cases based on the criteria cited above. The OATz delivers a large aspheric ablation beginning at the junction of the programmed optical and transition zones and expanding to the periphery of the transition zone. In the transition zone, the volume of ablation gradually decreases as the ablation expands peripherally to minimize changes in corneal curvature. With OATz, ocular or corneal higher order aberrations are not treated. For the remainder of this article, we will refer to the treatment zones rather than optical and transition zones as it is a more accurate definition of the ablation diameter for OATz.10

For OPDCAT treatment simulation, the Final Fit software was used based on the corneal topography data, ocular wavefront aberrations, and objective refraction data obtained from the OPD-Scan, which was used to simulate the postoperative corneal shape and generate shot data for treatment. An optical zone of 4.5 mm and a transition zone of 8.0 mm with profile #610 were used for all OPDCAT cases. Two fundamental differences occur between OPDCAT and OATz. First, OPDCAT delivers an aspheric ablation to both the programmed optical and transition zones and second, OPDCAT treats the ocular higher order aberrations, including spherical aberration, to the 8th Zernike order whereas OATz does not. The irregularity simulated in Final Fit for the OPDCAT used an optical zone of 6.0 mm and a transition zone of 8.0 mm. Eighty percent of the calculated irregularity treatment was actually programmed for treatment to spare tissue.

All treatments were targeted for emmetropia with gram-adjusted preoperative manifest refraction.

### SURGERIES

All surgeries were performed at the Minamiaoyama Eye Clinic from September 2004 to October 2005 by four surgeons (Y.H., I.T., T.Y., and K.T.) using the same surgical technique and the same excimer laser. All eyes undergoing surgery were prepared in a sterile fashion. One or two drops of topical anesthetic were instilled and a sterile drape was used to isolate the sur-
A lid speculum was inserted to allow maximum exposure of the globe. The MK-2000 (NIDEK Co Ltd) automated mechanical microkeratome was used to create nasal lamellar hinged flaps that were 8.5 mm to accommodate the full diameter of the ablation. The 130-, 145-, or 160-µm depth blade holders were used in this study. Meticulous alignment of the eye with the laser was achieved with a 200-Hz infrared eye tracker centered on the physiologic pupil. Torsional errors were corrected by enabling the torsion error detection function of the laser. The flap was reflected nasally and the ablation was delivered to the stroma. Patients fixated on a red fixation light throughout the ablation. The flap was repositioned and the interface was irrigated with balanced salt solution, removing any debris. Immediately after surgery, patients were instructed to instill topical antibiotic drops and topical corticosteroid drops five times per day for 7 days and ocular lubrication drops as needed.

**Excimer Laser**

All eyes underwent LASIK using the NIDEK EC-5000CXII excimer laser equipped with a 200-Hz infrared eye tracker and multipoint ablation and torsion error detection modules. The OATz or OPDCAT treatments were delivered to the corneal stroma. The laser ablation algorithms used a rotating scanning-slit delivery system that corrected for lower order aberrations such as sphere and cylinder. The multipoint ablation module in the laser corrected corneal irregularities using a 1-mm spot ablation size that delivered up to six spots simultaneously.

**DATA ANALYSIS**

Statistical analysis of the data was performed using Statistica Version 6.1 software (StatSoft Inc, Tulsa, Okla). The $t$ test was used to analyze UCVA, BSCVA, MRSE, higher order aberration RMS, and corneal asphericity (Q-value) between groups. Modulation transfer function (MTF) and higher order Strehl ratios were calculated using the OPD-Station visual simulation software (NIDEK Co Ltd). In the OPD-Station, MTF ratios of the area under the higher order aberration curve compared to the area under the curve of a sample of emmetropes were calculated. The closer the ratio to 1 (in some cases higher than 1) the closer (or better) the objective visual performance to that of an
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emmetropic eye. The Mann-Whitney U test was used to analyze safety and the subjective questionnaire scores between groups. Analysis of variance (ANOVA) was used to analyze changes in contrast sensitivity between groups. A P value <.05 was considered statistically significant.

RESULTS

Preoperative visual acuity, MRSE, higher order aberrations, and corneal asphericity for all groups and subgroups are shown in Table 1. Preoperative spherical aberration, higher order aberration RMS, and MRSE were statistically significantly different among groups and subgroups (Table 1). At 3 months postoperatively, 88.3% (242/274) of eyes were available for follow-up—93 eyes in the OPDCAT group and 149 eyes in the OATz group. Postoperative visual acuity, MRSE, higher order aberrations, and corneal asphericity of all groups and subgroups are shown in Table 2. No intra- or postoperative complications were noted in this study.

REFRACTIVE OUTCOMES

The change in MRSE from preoperatively to 3 months postoperatively for the OPDCAT and OATz groups is shown in Figure 1. At 3 months postoperatively, no statistically significant difference in postoperative MRSE between the two groups was seen (P >.05).

For the OPDCAT group, 91.4% of eyes were within 0.50 D of intended MRSE and all eyes were within 1.00 D of intended MRSE 3 months postoperatively. For the OATz group, 90.6% and 98.0% of eyes were within 0.50 D and 1.00 D, respectively, of intended MRSE 3 months postoperatively. In the low MRSE OPDCAT subgroup, 92.6% of eyes were within 0.50 D of intended MRSE and all eyes were within 1.00 D of the intended MRSE. In the low MRSE OATz subgroup, 95.8% and 99.0% of eyes were within 0.50 D and 1.00 D, respectively, of intended MRSE. At 3 months postoperatively, no statistically significant difference in postoperative MRSE between the low MRSE subgroups of eyes was noted (P >.05) (Table 2). For the high MRSE OPDCAT subgroup, 92.3% of eyes were within 0.50 D of intended MRSE and all eyes were within 1.00 D of intended MRSE. For the high MRSE OATz subgroup, 86.8% and 96.2% of eyes were within 0.50 D and 1.00 D, respectively, of intended MRSE. At 3 months postoperatively, no statistically significant difference in postoperative MRSE between the high MRSE subgroups of eyes was noted (P >.05) (Table 2).

For the low higher order aberration OPDCAT subgroup, 93.0% of eyes were within 0.50 D of the intended MRSE and all eyes were within 1.00 D of intended MRSE. For the low higher order aberration OATz subgroup, 91.4% and 96.3% of eyes were within 0.50 D and 1.00 D, respectively, of intended MRSE. At 3 months postoperatively, no statistically significant difference in postoperative MRSE between the low higher order aberration subgroups was noted (P >.05) (Table 2). For the high higher order aberration OPDCAT subgroup, 90.9% of eyes were within 0.50 D of the intended MRSE and all eyes were within 1.00 D of intended MRSE. For the high higher order aberration OATz subgroup, 90.5% of eyes were within 0.50 D of intended MRSE and all eyes were within 1.00 D of intended MRSE. At 3 months postoperatively,
no statistically significant difference in postoperative MRSE between the high higher order aberration subgroups was noted (P > .05) (Table 2).

At 3 months postoperatively, there was no difference in UCVA between the OPDCAT and OATz groups (P > .05) (Fig 2). At 3 months postoperatively, there were no statistically significant differences in mean UCVA or mean change in UCVA among all groups and subgroups (Table 2). No statistically significant difference in safety among groups and subgroups was noted (P > .05) (Fig 3).

**Ocular Aberrations and Corneal Asphericity**

Postoperatively, total ocular higher order aberrations, spherical aberration, coma, and corneal asphericity (Q-value) were statistically significantly different among groups and subgroups (P < .05) (Table 2).

The mean change in corneal asphericity from preoperatively to 3 months postoperatively was +0.31 ± 0.30 (range: −0.47 to 1.25) for the OPDCAT group and +0.51 ± 0.35 (range: −0.28 to 1.85) for the OATz group. In both cases, the change indicated a more oblate cornea. The mean change in corneal asphericity between the OPDCAT and OATz groups was statistically significant (P < .05).

For the low MRSE subgroups, the mean change in corneal asphericity from preoperatively to 3 months postoperatively was 0.10 ± 0.08 (range: −0.47 to 0.86) for the OPDCAT group and 0.17 ± 0.10 (range: −0.28 to 1.20) for the OATz group. The mean change in corneal asphericity between these two subgroups was statistically significant (P < .05). For the high MRSE subgroup, the mean change in corneal asphericity was 0.45 ± 0.30 (range: −0.19 to 1.25) for the OPDCAT group and 0.72 ± 0.38 (range: 0.09 to 1.85) for the OATz group. The mean change in corneal asphericity between these two subgroups was statistically significant (P < .05).

For the low higher order aberration subgroups, the mean change in corneal asphericity was 0.35 ± 0.31 (range: −0.47 to 1.25) for the OPDCAT group and 0.57 ± 0.41 (range: −0.28 to 1.85) for the OATz group. The mean change in corneal asphericity between these two subgroups was statistically significant (P < .05). For the high higher order aberration subgroups, the mean change in corneal asphericity was 0.27 ± 0.29 (range: −0.23 to 0.97) for the OPDCAT group and 0.43 ± 0.26 (range: −0.14 to 1.14) for the OATz group. The mean change in corneal asphericity between these two subgroups was statistically significant (P < .05).

The high higher order aberration OPDCAT subgroup had a mean change in higher order aberration RMS of 0.07 ± 0.15 µm (range: −0.26 to 0.38 µm) and 0.19 ± 0.12 µm (range: −0.02 to 0.51 µm) for the low higher order aberration OPDCAT subgroup. A statistically significant greater change in higher order aberration RMS for the low higher order aberration OPDCAT subgroup compared with the high higher order aberration OPDCAT subgroup was noted (P < .05).
higher order aberration OATz subgroup had a mean change in higher order aberration RMS of 0.20±0.18 µm (range: −0.12 to 0.70 µm) and 0.32±0.19 µm (range: −0.02 to 0.97 µm) for the low higher order aberration OATz subgroup. A statistically significantly greater change in higher order aberration RMS for the low higher order aberration OATz subgroup compared with the high higher order aberration OATz subgroup was noted (P<.05).

The MTF ratio for the high MRSE OPDCAT subgroup was 0.63±0.14 (range: 0.44 to 0.99) preoperatively and 3 months postoperatively was 0.48±0.12 (range: 0.32 to 0.96). The MTF ratio for the high MRSE OATz subgroup was 0.71±0.22 (range: 0.40 to 1.32) preoperatively and 3 months postoperatively was 0.41±0.08 (range: 0.26 to 0.61). The preoperative MTF ratio was statistically significantly higher in the high MRSE OATz subgroup (P<.05). A statistically significant difference in the postoperative change of the MTF ratios favoring the high MRSE OPDCAT subgroup was noted (P<.05).

The MTF ratio for the low MRSE OPDCAT subgroup was 0.67±0.13 (range: 0.43 to 1.02) preoperatively and 3 months postoperatively was 0.57±0.09 (range: 0.34 to 0.98). The preoperative MTF ratios were not significantly different (P>.05). The change in MTF ratio postoperatively was statistically significantly different among groups (P<.05).

The MTF ratio for the high higher order aberration OPDCAT subgroup was 0.57±0.09 (range: 0.43 to 1.21) preoperatively and 3 months postoperatively was 0.47±0.10 (range: 0.26 to 0.98). The preoperative MTF ratios were not significantly different (P>.05). A statistically significant difference in the postoperative change of the MTF ratios favoring the low MRSE OPDCAT subgroup was noted (P<.05).

The MTF ratio for the low higher order aberration OPDCAT subgroup was 0.69±0.16 (range: 0.43 to 1.21) preoperatively and 3 months postoperatively was 0.50±0.10 (range: 0.34 to 0.98). The preoperative MTF ratios were not significantly different (P>.05). A statistically significant difference in the postoperative change of the MTF ratios favoring the low MRSE OATz subgroup was noted (P<.05).

The MTF ratio for the low higher order aberration OATz subgroup was 0.70±0.18 (range: 0.40 to 1.32) preoperatively and 3 months postoperatively was 0.47±0.10 (range: 0.26 to 0.98). The preoperative MTF ratios were not significantly different (P>.05). The change in MTF ratio postoperatively was statistically significantly different among groups (P<.05).
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The MTF ratio for the low higher order aberration OPDCAT subgroup was 0.75±0.11 (range: 0.58 to 1.02) preoperatively and 3 months postoperatively was 0.56±0.13 (range: 0.33 to 0.96). The MTF ratio for the low higher order aberration OATz subgroup was 0.80±0.17 (range: 0.45 to 1.32) preoperatively and 3 months postoperatively was 0.48±0.11 (range: 0.26 to 0.98). The preoperative MTF ratios were not significantly different (P>.05). The postoperative change of the MTF ratios was statistically significant favoring the low higher order aberration OPDCAT subgroup (P<.05).

CONTRAST SENSITIVITY AND PATIENT SATISFACTION

The change in contrast sensitivity for all groups and subgroups is shown in Figure 4. Only the subgroup of eyes with MRSE ≤−6.00 D did not show a statistically significant difference in contrast sensitivity among OPDCAT and OATz groups (P>.05) (see Fig 4). Patient satisfaction with vision at night is shown in Figure 5. No statistically significant difference in patient satisfaction with vision at night among groups or subgroups was noted (P>.05). Overall patient satisfaction with the LASIK procedure is shown in Figure 6. No statistically significant difference in overall patient satisfaction among groups and subgroups was noted (P>.05).

ABLATION DEPTH

Mean ablation depth for the OPDCAT group was 87.46±27.72 µm (range: 35.2 to 153.3 µm) of which 4.63±1.36 µm (range: 2.0 to 7.70 µm) was used for the irregularity treatment. The ablation rate for the OPDCAT treatment was 16.65 µm/D. The mean ablation depth for the OATz group was 82.20±23.06 µm.
The ablation rate for the OATz treatments was 15.94 µm/D. The ablation rate was statistically significantly lower for OATz treatments (P<.05).

**FLAP THICKNESS**

Mean flap thickness was 107.6±13.9 µm (range: 84 to 145 µm) using the 130-µm blade holder (n=41 eyes), 117.4±22.4 µm (range: 77 to 146 µm) using the 145-µm blade holder (n=7 eyes), and 125.9±19.2 µm (range: 88 to 179 µm) using the 160-µm blade holder (n=226 eyes).

**DISCUSSION**

This investigation of myopic LASIK comparing OPDCAT to OATz was conducted to determine whether differences were present in refractive outcomes, higher order aberration, objective visual quality, and patient satisfaction between these two ablation algorithms. We found that refractive outcomes among groups or subgroups were equivalent. However, a statistically significant lower induction of higher order aberration and less change in corneal asphericity in the OPDCAT group was noted (Table 2). The OPDCAT algorithm also seemed more likely to maintain objective visual quality as measured by mesopic contrast sensitivity (see Fig 4). However, no differences in patient satisfaction were demonstrated.

To our knowledge, only one other study compares the outcomes of LASIK using OPDCAT and OATz. However, comparison with our results is difficult as Kermani et al included both OPDCAT and customized aspheric treatment zone (a topography-guided algorithm) as one group in most of their analyses. Our refractive outcomes do agree with Kermani et al who found no difference between OATz and OPDCAT.

In the broader category of comparing aspheric algorithms with wavefront LASIK, there is only one peer-reviewed paper to date, which also found no difference in the refractive outcomes between the two groups. Koller et al found no difference in the induction of wavefront aberrations except for coma, which was lower with the wavefront-guided custom ablation profile. Our results show there is greater induction of total ocular higher order aberrations, spherical aberrations, and coma with OATz. Our study differs in one important aspect from the study by

![Figure 6. Graphs show overall patient satisfaction 3 months after LASIK using the OPD-guided customized aspheric treatment algorithm (OPDCAT group) or the optimized aspheric treatment zone algorithm (OATz group) using the NIDEK Advanced Vision Excimer Laser System for A) all eyes in the OPDCAT and OATz groups, B) the subgroup of eyes with −6.00 diopters (D) manifest refraction spherical equivalent (MRSE), C) the subgroup of eyes with −6.00 D MRSE, D) the subgroup of eyes with −0.40 µm higher order aberration root-mean-square (RMS), and E) the subgroup of eyes with −0.40 µm of higher order aberration RMS.](image-url)
Koller et al—used a fully aspheric treatment based on patient-specific corneal curvature over the entire ablation diameter combined with wavefront aberrations of the eye, whereas the wavefront-guided algorithm they used did not include an aspheric algorithm.

The customization of corneal asphericity along the entire ablation diameter coupled with the treatment of higher order aberrations likely led to the reduced changes in corneal shape and the lower induction of spherical aberration in OPDCAT-treated eyes. In contrast, the OATz algorithm delivers an aspheric algorithm starting from the periphery of the optical zone outwards. The change in corneal asphericity was statistically significantly lower in all OPDCAT subgroups with the exception of the subgroups with \( \geq 0.40 \mu m \) higher order aberration RMS (Table 2). This lower induced change in corneal asphericity for the OPDCAT group and subgroups was a direct consequence of using aspheric algorithms over the entire treatment diameter rather than creating partial asphericity over the treatment diameter. One explanation of the higher induced asphericity in the OPDCAT subgroup with \( \geq 0.40 \mu m \) higher order aberration RMS may be due to the presence of higher levels of corneal spherical aberration compared with the respective OATz subgroup. However, we cannot confirm this observation as analysis of higher order aberrations of the cornea were not conducted in this study.

Aspheric algorithms appear to have some advantages over conventional algorithms. In a previous paper, we reported that OATz aspheric treatment delivered larger effective optical zones and better objective visual quality compared with conventional ablation. Comparing OPDCAT to OATz, we found better objective visual quality for the OPDCAT-treated eyes, which may be an incremental step in further decreasing the likelihood of complaints of night vision disturbances and increasing patient satisfaction postoperatively. We found a lower induction of spherical aberrations in the OPDCAT group and all subgroups compared with the respective OATz group and subgroups (Table 2). In comparison with conventional LASIK, we found minimal changes in low contrast performance for both the OPDCAT and OATz groups. However, a comparative study using all three ablation algorithms (conventional, OATz, and OPDCAT) would be required to conclusively address the benefits of one algorithm over the other.

Laser-induced spherical aberration has been implicated as a source of scotopic halos postoperatively. In this study, we found minimal induction of spherical aberration compared with that reported for conventional ablations. Excimer laser–induced spherical aberration has been shown to have a deleterious effect on objective visual quality. However, this relationship is likely related to the magnitude of myopic correction in conventional ablations.

The objective visual quality (MTF) was better for all OPDCAT-related subgroups. Postoperatively, the majority of patients found vision at night was more than adequate for daily activities (see Fig 5). Patient satisfaction was similar in both groups and subgroups despite the statistically significant differences in optical quality and objective visual quality. This observation is likely due to the use of an “in-house” questionnaire, which needs further validation. For example, the questions may not be structured adequately to detect changes in patient satisfaction among groups or subgroups or the grading scale may be too general (eg, very satisfied, satisfied, a little dissatisfied, and dissatisfied). However, accounting for the neural processing of the objective visual quality is beyond the scope of this study. Lastly, RMS values alone do not fully address visual quality, and the actual aberrations that combine to form the higher order aberration structure of the eye have varying effects on visual performance. However, despite these drawbacks, patient satisfaction was high in all groups and subgroups with over 80% of patients being satisfied to very satisfied postoperatively (see Fig 6).

In the current study, 4.5-mm optical zones and 8.0-mm transition zones (8.0-mm treatment zones) were used. It is reasonable to assume the use of larger treatment zones where possible may further increase contrast sensitivity and visual quality at night.

Recent studies have found there is a difference in the magnitude of induced higher order aberration dependent on the magnitude of preoperative higher order aberration regardless of the wavefront laser platform used. Results from Pop and Payette and Venter indicate a greater induction of higher order aberration in patients with \(< 0.30 \mu m \) to \( 0.40 \mu m \). Interestingly, Pop and Payette used the topography-guided CATz algorithm whereas Venter used the OPDCAT algorithm. Our results concur with both studies as both the OATz and OPDCAT algorithms show a greater induction of higher order aberration in eyes with \(< 0.40 \mu m \) higher order aberration preoperatively. Based on our results and those of others, we believe the trend of “the lower the preoperative aberration, the higher the induction” extends across laser platforms and algorithms. The cause of the phenomena, whether endemic to the laser ablation or the eye or a combination of factors, will need to be addressed in future studies.

There are some limitations of this study. An unvalidated patient questionnaire was used. A longer postoperative follow-up may elucidate different results.
Separate analyses of corneal higher order aberration may aid in explaining some of the observed changes in corneal asphericity. The measurement of effective optical zone and correlation to contrast sensitivity may aid in further explanation of objective visual quality. Despite these drawbacks, the outcomes of this study will further aid in the appropriate preoperative selection of refractive surgery candidates. For example, patients with \(-6.00\) D preoperative MRSE and \(>0.40\) \(\mu\)m higher order aberration may have greater benefit from OPDCAT due to the reduced induction of higher order aberration and reduced changes in corneal asphericity. Our results contradict Koller et al\(^6\) who advocated using aspheric algorithms for the majority of patients and reserving wavefront-guided treatments for a select few. Koller et al\(^6\) partially base their conclusions on the limitations of the technology used such as the increased patient work-up time due to the use of an aberrometer that required a pharmacologically dilated pupil. However, not all platforms require dilation and different aberrometers perform measurement at different rates. For example, the OPD-Scan used in our study acquires wavefront data on a physiologically dilated pupil within 0.50 seconds. We suggest that the OPDCAT algorithm is likely the treatment of choice for most patients as it induces less change in corneal shape and wavefront aberrations and maintains visual quality. However, OPDCAT requires slightly greater tissue removal compared with OATz and hence a balance between the ablation depth and other clinical parameters is warranted.

We found that both the OATz and OPDCAT algorithms produce similar refractive outcomes, visual acuity, and patient satisfaction. However, the OPDCAT algorithm produces better optical quality and objective visual quality and should be regarded as the treatment of choice for the primary myopic refractive surgery candidate.

**AUTHOR CONTRIBUTIONS**

Study concept and design (Y.H.); data collection (Y.H., I.T., T.Y., K.T.); analysis and interpretation of data (Y.H., I.T.); drafting of the manuscript (Y.H.); critical revision of the manuscript (Y.H., I.T., T.Y., K.T.)

**REFERENCES**