ARTICLE

Surgical treatment of presbyopia with central presbyopic keratomileusis: One-year results

Gaëlle Ho Wang Yin, MD, MSc, Colm McAlinden, MD, MB BCh, MSc, PhD, Emmanuelle Pieri, OD, Claire Giulardi, OD, Guillaume Holweck, MD, Louis Hoffart, MD, PhD

PURPOSE: To assess the effectiveness, refractive outcomes, and quality of vision of central presbyopic laser in situ keratomileusis (LASIK) performed with the Custom Q algorithm (Wavelight EX500).

SETTING: Ophthalmology Department, Hôpital de la Timone, Marseille, France.

DESIGN: Prospective cohort study.

METHODS: This study was performed between February 2013 and January 2015. Patients with hyperopia were treated with central presbyopic LASIK. Distance, near, and intermediate visual acuities; objective and subjective refractions; Q factor; keratometry (K); corneal aberrations, and a quality-of-vision questionnaire were evaluated preoperatively and postoperatively. The dominant eye was treated with standard LASIK for distance vision and the nondominant eye for near vision using a Q factor modulation.

RESULTS: The study comprised 138 eyes of 28 men and 41 women. The median age was 53.84 years $\pm$ 4.2 (SD). One year after surgery, the mean binocular uncorrected distance visual acuity was -0.04 ± 0.05 logMAR (20/20), the mean binocular uncorrected near visual acuity was 0.10 ± 0.08 logMAR (Jaeger 2), and the mean binocular uncorrected intermediate visual acuity was -0.13 ± 0.14 logMAR (20/20). The mean K in nondominant eyes was statistically higher than the mean K in dominant eyes (43.93 ± 1.77 diopters [D] versus 45.85 ± 1.47 D) ($P = .002$). More than 95% of patients were satisfied 3 months after surgery, and at 6 months, 100% said they would recommend the surgery.

CONCLUSION: Central presbyopic LASIK with corneal asphericity modulation using the monovision correction algorithm was effective and safe for presbyopia treatment.

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Presbyopia correction remains a significant challenge for ophthalmologists.[1] Many surgical techniques have been described; however, all involve some degree of compromise between distance and near visual acuity outcomes. These surgical options include intraocular surgery (refractive lens exchange, cataract surgery with multifocal or accommodating intraocular lenses, and monovision), and corneal surgery such as corneal inlays or refractive corneal surface reshaping.

Among the corneal refractive procedures, laser in situ keratomileusis (LASIK) is the most widely performed worldwide and numerous presbyopic LASIK procedures were proposed with centered,[2] peripheral,[3] and off-centered[4] correction algorithms.[5] In presbyopic LASIK surgery, some degree of monovision is also usually added because it has been shown that anisometropia greater than 1.0 diopter (D) is effective for improving visual acuity.[6,7] Success of the procedure depends on suppression of the blurred retinal image in the defocused eye.[8] Furthermore, anisometropia greater than 2.0 D can reduce intermediate visual acuity, contrast sensitivity, and depth

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perception.[9] To overcome these limitations and increase the results of near visual acuity, Reinstein et al.[10] proposed using spherical aberration to increase depth of focus and minimize anisometropia with a nonlinear aspheric ablation profile.

The purpose of the present study was to evaluate the effectiveness, refractive outcomes, and subjective quality of vision of patients who had presbyopic surgery by central presbyopic LASIK with corneal asphericity modulation by the Custom Q algorithm of the Wavelight EX500 wavefront-guided excimer laser (Alcon Surgical, Inc.).

PATIENTS AND METHODS

This prospective study was performed at a single-center university ophthalmology department (Hôpital de la Timone, Marseille, France). All patients were informed and gave their consent to the study in accordance with the tenets of the Declaration of Helsinki and the Institutional Review Board, Sud-Méditerranée I, Hôpital Sainte Marguerite, Marseille, France.

The inclusion criteria were age between 40 years and 65 years, spherical refractive error between 0.0 D and +6.0 D, corneal cylinder up to 3.0 D, preoperative corrected distance visual acuity (CDVA) of 20/20 or better, central corneal thickness more than 500 μm, and no other ocular pathology or previous ocular surgery.

A complete preoperative ophthalmologic examination was performed that included manifest refraction, cycloplegic refraction, slitlamp microscopy of the anterior segment, dilated fundoscopy, Goldmann tonometry, and corneal topography (Pentacam, Oculus Optikgeräte GmbH). Uncorrected distance visual acuity (UDVA) and CDVA were assessed on a decimal scale. Uncorrected near visual acuity (UNVA), uncorrected intermediate visual acuity (UIVA), and distance-corrected near visual acuity were assessed with Parinaud reading charts at 33 cm and 60 cm. Ocular dominance was determined using the hole-in-the-card test and the preferential blur test.

All surgeries were performed by experienced surgeons between February 2013 and January 2015. Under topical anesthesia, a 9.2 mm diameter superior 40-degree hinged corneal flap with a 90-degree side-cut and a 120 μm thickness was dissected using a femtosecond laser (520F, Bausch & Lomb, Inc.). The flap was manually raised, and photoablation was performed using the wavefront-guided excimer laser. The postoperative treatment included tobramycin and dexamethasone (Tobradex) 4 times a day for 7 days and nonpreserved hyaluronic acid 0.18% lubricant eyedrops (Vismed).

The dominant eye was corrected for distance vision with the Wavefront Optimized algorithm and the nondominant eye was corrected with the Custom Q software set to a postoperative refractive target of −0.50 D and a postoperative corneal asphericity target Q between −0.60 and −0.80. This treatment aims to change the mean asphericity by adjusting the number of midperipheral laser pulses. The optical zone was planned at 6.5 mm in all cases, with a transition zone of 1.0 mm.

Patients were examined 7 days, 1 month, 3 months, 6 months, 9 months, and 1 year after surgery. All postoperative follow-up visits included measurement of monocular and binocular UDVA, UNVA, UIVA, CDVA, corrected near visual acuity, and manifest refraction. A subjective defocusing curve, under photopic conditions, was plotted at 1, 3, 6, 9, and 12 months. All the patients self-completed the Quality of Vision (QoV) questionnaire[11–14] on a monocular basis at 1, 3, 6, 9, and 12 months. Questionnaire responses were scored via Rasch-scaling.[15] Extreme measures (floor or ceiling effects) or outliers were not excluded. The Rasch model makes its estimates on the assumption that outliers are part of the randomness predicted by the model.

Statistical analyses were performed using XLstat-Pro 2015 software (version 2015.1.02, Addinsoft, Inc.). For quantitative values, mean comparisons were performed with a parametric paired Student *t* test. For subgroup analysis, a nonparametric Mann-Whitney test was used. A *P* value less than 0.05 was considered statistically significant. A Pearson test was used for correlation between quantitative values.

RESULTS

The study included 138 eyes from 69 patients with hyperopia with a mean age of 53.84 years ± 4.19 (SD) (range 47 to 64 years) at the time of surgery. There were 28 men (41%) and 41 women (59%). Table 1 shows the preoperative characteristics of the patient cohort.

Visual Acuity

Figure 1 shows the uncorrected cumulative binocular distance, near, and intermediate visual acuity in the cohort; Table 2 shows postoperative distance binocular UDVA, binocular UIVA, and binocular UNVA.

All 69 patients (100%) achieved a binocular UDVA of 20/20, 70% (48/69) achieved a binocular UNVA of at least Jaeger (J)2, 30% (21/69) achieved a binocular UNVA of J1, and 100% (69/69) achieved a binocular UIVA of 20/20 at 12 months. The binocular UDVA at 3 months was significantly better in patients

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From the Ophthalmology Department (Yin, Pieri, Giulardi, Hoffart), Aix-Marseille University, Assistance Publique Hôpitaux de Marseille, Hôpital de la Timone, and the Ophthalmology Department (Holweck), French Military Health Service, Laveran Hospital, Marseille, France; the Department of Surgery (McAlinden), Abertawe Bro Morgannwg University Health Board, Swansea, United Kingdom; Flinders University (McAlinden), Bedford Park, Adelaide, South Australia, Australia; Wenzhou Medical University (McAlinden), Wenzhou, Zhejiang, China.

Corresponding author: Louis Hoffart, MD, PhD, Service d'Ophtalmologie, Université d'Aix-Marseille, Hôpital de la Timone, 264, Rue Saint Pierre 13385, Marseille, Cedex 05, France. E-mail: louis.hoffart@ap-hm.fr.

Table 1. Preoperative and postoperative characteristics of the patients.

	Preoperative		One-year Postoperative	
Parameter	Mean ± SD	Range	Mean ± SD	Range
Spherical equivalent (D)	1.63 ± 0.97	0.00, 5.50	−0.28 ± 0.95	−2.50, 2.50
Cylinder (D)	−0.30 ± 0.39	−2.00, 0.75	−0.38 ± 0.33	−1.00, 0.00
Mean keratometry (D)	43.07 ± 1.32	40.15, 46.7	45.39 ± 1.65	41.95, 48.05
Anterior surface Q factor	−0.19 ± 0.12	−0.66, 0.01	−0.89 ± 0.36	−1.66, −0.38
Spherical aberrations (μm)	0.254 ± 0.086	0.022, 0.469	−0.19 ± 0.22	−0.617, 0.184
Vertical coma (μm)	−0.01 ± 0.173	−0.805, 0.669	−0.419 ± 0.505	−1.682, 0.267
Horizontal coma (μm)	−0.004 ± 0.168	−0.611, 0.534	0.033 ± 0.354	−0.577, 0.937

between the ages of 45 years and 50 years than in patients between the ages of 51 years and 55 years ($P = .04$) and 56 years and 60 years ($P = .04$). There was no significant correlation in binocular UDVA with the preoperative Q factor. The binocular UDVA was significantly better in patients treated with a planned −0.8 Δ Q (Table 3). Table 4 shows the characteristics of patients with UNVA better than 0.1 logMAR (J2).

Spherical Equivalent

Figure 2 shows the spherical equivalent (SE) refraction in the dominant eyes and nondominant eyes. The SE refraction in dominant eyes was stable between 1 month and 1 year postoperatively ($P = .101$). Moreover, a progressive shift in myopia toward emmetropia was observed in nondominant eyes (mean change from −1.3 D at 1 month to −0.7 D at 1 year; $P = .03$). No statistical correlation was found between

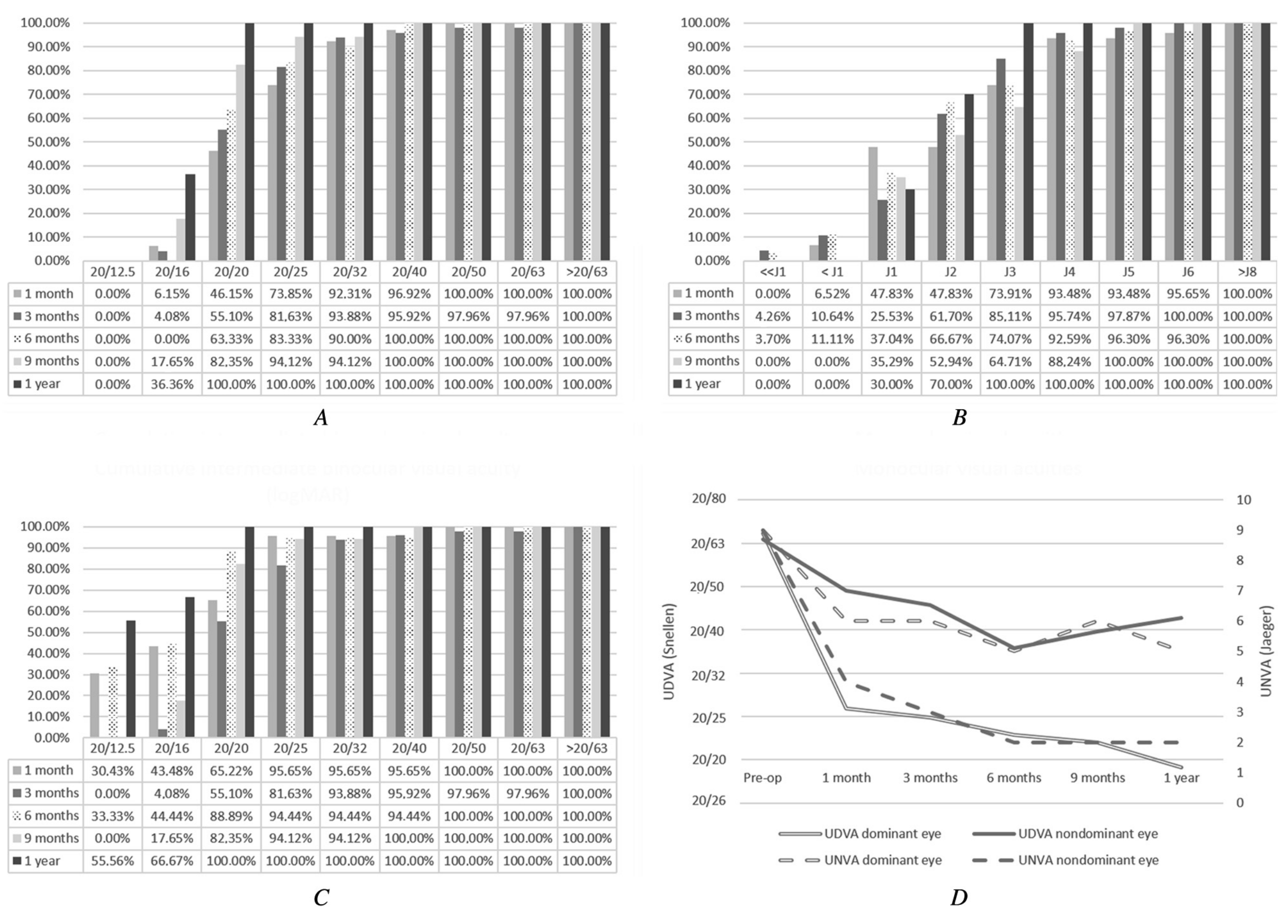


Figure 1. *A*: Cumulative binocular UDVA (logMAR) over time. *B*: Cumulative near binocular visual acuity (logMAR) over time. *C*: Cumulative intermediate binocular visual acuity (logMAR) over time. *D*: Monocular visual acuities. Visual acuities in Snellen units (distance and intermediate visual acuities) and Jaeger (near visual acuity) (UDVA = uncorrected distance visual acuity; UNVA = uncorrected near visual acuity).

Table 2. Postoperative visual acuity results in logMAR units (Snellen and Jaeger equivalent).

Parameter	Visual Acuity	Mean ± SD	Range	*P* Value
Binocular UDVA				
1 month	20/25	0.07 ± 0.11	−0.1, 0.4	.46
3 months	20/25	0.06 ± 0.09	−0.1, 0.4	.72
6 months	20/20	0.03 ± 0.07	0.0, 0.3	.09
9 months	20/20	−0.01 ± 0.05	−0.1, 0.1	.07
12 months	20/20	−0.04 ± 0.05	−0.1, 0.0	.07
Binocular UIVA				
1 month	20/20	−0.01 ± 0.16	−0.2, 0.4	.28
3 months	20/20	−0.04 ± 0.13	−0.3, 0.3	.30
6 months	20/20	−0.02 ± 0.15	−0.2, 0.4	.50
9 months	20/20	−0.07 ± 0.11	−0.3, 0.0	.06
12 months	20/20	−0.12 ± 0.13	−0.3, 0.0	.96
Binocular UNVA				
1 month	J2	0.13 ± 0.12	−0.1, 0.5	.22
3 months	J2	0.11 ± 0.15	−0.3, 0.5	.66
6 months	J2	0.13 ± 0.22	−0.3, 0.5	.60
9 months	J3	0.15 ± 0.15	0.0, 0.4	.06
12 months	J2	0.10 ± 0.08	0.0, 0.2	.06

J = Jaeger; UDVA = uncorrected distance visual acuity; UIVA = uncorrected intermediate visual acuity; UNVA = uncorrected near visual acuity

the postoperative SE refraction and patient age ($r = -0.258$, $P = .06$) or preoperative ametropia ($r = 0.132$, $P = .298$).

Keratometry

The preoperative mean keratometry (K) was 43.06 ± 1.34 D (range 40.15 to 46.7 D) in dominant eyes and 43.09 ± 1.31 D (range 40.2 to 46.5 D) in nondominant eyes. One year after surgery, the mean K in nondominant eyes was statistically greater than in dominant eyes (43.93 ± 1.77 D [range 42.75 to 47.5 D] versus 45.85 ± 1.47 D [range 42.85 to 49.2 D]) ($P = .002$).

Corneal Aberrometry

Dominant Eye One year postoperatively, spherical aberration was negative and significantly different from preoperative measurements (0.253 ± 0.09 μm [range 0.022 to 0.441 μm] and −0.103 ± 0.204 μm [range −0.464 to 0.184 μm], respectively) ($P < .0001$). Vertical coma was also statistically different (0.013 ± 0.21 μm [range −0.280 to 0.260 μm] and −0.284 ± 0.323 μm [range −0.879 to 0.267], respectively) ($P = .039$). However, the change in horizontal coma was not significant between the timepoints (−0.021 ± 0.108 μm [range −0.805 to 0.669 μm] versus −0.138 ± 0.250 μm [range −0.577 to 0.154 μm], respectively) ($P = .260$).

Nondominant Eye At 1 year, spherical aberration was negative and significantly different from preoperatively (−0.286 ± 0.203 μm [range −0.617 to 0.065 μm] versus 0.255 ± 0.08 μm [range −0.177 to 0.305 μm]) ($P < .0001$) (Figure 3). Vertical coma (−0.014 ± 0.212 μm [range −0.611 to 0.534 μm] versus −0.699 ± 0.582 μm [range −1.682 to −0.200 μm]) and horizontal coma (0.028 ± 0.104 μm [range −0.236 to 0.240 μm] versus 0.205 ± 0.370 μm [range −0.368 to 0.937 μm]) were also significantly different ($P < .0001$ and $P = .031$, respectively). There was a positive correlation between the postoperative Q factor and spherical aberrations ($r = 0.8$, $P < .0001$).

Postoperative Q factor Predictability

There was a significant correlation between the attempted and the achieved postoperative Q factor in nondominant eyes ($r = 0.260$, $P = .041$).

Safety

One month after surgery, 1 eye (1.22%) lost 2 lines and 5 eyes (6.0%) lost 1 line of CDVA. The same results were found at the later timepoints; 16 eyes (19.5%) gained 1 line or more lines, and 18 eyes of 16 patients needed a refractive retreatment before 1 year, 7 in nondominant eyes and 7 in dominant eyes. Two patients needed a bilateral retreatment procedure. These patients were not included in the 1-year data (Figure 4).

Quality of Vision

Subjective Satisfaction Sixty-three (91.3%) of 69 patients were satisfied with the results of the surgery with regard to their everyday activities at 1 month, 95.7% (66/69) at 3 months, and up to 100% (69/69) at 9 months. Sixty-two (89.9%) of 69 patients said they would recommend the surgery 1 month after surgery, and up to 100% (69/69) would recommend it 6 months after surgery.

Subjective Visual Adverse Effects One month after surgery, in the individual questions from the QoV questionnaire, patients reported experiencing significantly increased halos ($P = .005$), blurred vision ($P = .006$), diplopia ($P < .0001$), visual fluctuation ($P < .0001$), focusing difficulties ($P < .0001$), and depth-perception difficulties ($P = .005$) in both their dominant eye and nondominant eye (Figure 5).

Quality of Vision Score There were no reported statistical differences in QoV scores between dominant eyes and nondominant eyes ($P > .05$). The QoV scores for frequency, severity, and bothersome subscales of the questionnaire are shown in Figure 5, *A*, for dominant eyes and Figure 5, *B*, for nondominant eyes. Visual

Table 3. Preoperative and postoperative visual acuity results correlated to postoperative Q factor change in logMAR units (Snellen or Jaeger equivalent).

	−0.8 Δ Q		−0.6 Δ Q		
Parameter	Mean ± SD	Visual Acuity	Mean ± SD	Visual Acuity	*P* Value
Preoperative					
Distance binocular visual acuity	0.42 ± 0.55	20/50	0.36 ± 0.46	20/50	.618
Near binocular visual acuity	0.78 ± 0.20	J12	0.78 ± 0.43	J12	NS
Intermediate binocular visual acuity	—	—	—	—	—
Distance visual acuity nondominant eye	0.43 ± 0.40	20/50	0.45 ± 0.47	20/60	.619
Near visual acuity nondominant eye	—	—	—	—	—
1 month					
Distance binocular visual acuity	0.08 ± 0.12	20/25	0.039 ± 0.060	20/20	.247
Near binocular visual acuity	0.16 ± 0.19	J3	0.11 ± 0.10	J2	.716
Intermediate binocular visual acuity	−0.053 ± 0.150	20/16	−0.075 ± 0.096	20/16	.734
Distance visual acuity nondominant eye	0.39 ± 0.25	20/50	0.35 ± 0.28	20/50	.263
Near visual acuity nondominant eye	0.17 ± 0.24	J3	0.16 ± 0.11	J3	.623
3 months					
Distance binocular visual acuity	0.068 ± 0.140	20/20	0.051 ± 0.070	20/20	.644
Near binocular visual acuity	0.094 ± 0.170	J2	0.15 ± 0.14	J3	.704
Intermediate binocular visual acuity	−0.023 ± 0.140	20/20	0.00 ± 0.21	20/20	.938
Distance visual acuity nondominant eye	0.34 ± 0.27	20/40	0.39 ± 0.36	20/50	.804
Near visual acuity nondominant eye	0.12 ± 0.16	J2	0.18 ± 0.18	J3	.315
6 months					
Distance binocular visual acuity	0.078 ± 0.100	20/25	0.009 ± 0.030	20/20	.024
Near binocular visual acuity	0.089 ± 0.180	J2	0.12 ± 0.11	J2	.833
Intermediate binocular visual acuity	−0.033 ± 0.225	20/20	−0.038 ± 0.100	20/20	.556
Distance visual acuity nondominant eye	0.39 ± 0.25	20/50	0.15 ± 0.14	20/30	.04
Near visual acuity nondominant eye	0.10 ± 0.15	J2	0.15 ± 0.15	J3	.448
9 months					
Distance binocular visual acuity	0.007 ± 0.100	20/20	0.000 ± 0.001	20/20	.63
Near binocular visual acuity	0.16 ± 0.15	J3	0.19 ± 0.01	J3	.846
Intermediate binocular visual acuity	−0.033 ± 0.060	20/20	−0.05 ± 0.06	20/16	<.0001
Distance visual acuity nondominant eye	0.31 ± 0.26	20/40	0.26 ± 0.21	20/40	.638
Near visual acuity nondominant eye	0.10 ± 0.10	J2	0.25 ± 0.20	J4	.489
12 months					
Distance binocular visual acuity	−0.05 ± 0.05	20/16	−0.025 ± 0.005	20/20	<.0001
Near binocular visual acuity	0.08 ± 0.07	J2	0.13 ± 0.08	J2	.695
Intermediate binocular visual acuity	−0.13 ± 0.15	20/16	−0.13 ± 0.15	20/16	.914
Distance visual acuity nondominant eye	0.35 ± 0.24	20/40	0.28 ± 0.34	20/40	.619
Near visual acuity nondominant eye	0.10 ± 0.10	J2	0.19 ± 0.01	J3	.286

J = Jaeger; NS = not significant

side effects were at the highest frequency and intensity at the first postoperative month and started to decrease at 3 months, resuming to baseline levels 1 year after surgery.

DISCUSSION

Within the past decade, several LASIK procedures have been used to correct presbyopia.[16,17] Presbyopic LASIK treatment uses the principles of LASIK surgery to create a multifocal corneal surface for correcting far vision while simultaneously reducing the near spectacle dependency in presbyopic patients.

Off-centered presbyopic LASIK[2] relied on an inferior off-center ablation profile to create specific higher-order aberrations such as vertical coma to improve near vision. The results were not satisfying,

Table 4. Postoperative characteristics of patients with UNVA worse than 0.1 logMAR.

Parameter	Mean ± SD
Spherical equivalent (D)	−1.49 ± 1.22
Targeted Q factor	−0.67 ± 0.68
Mean keratometry (D)	45.59 ± 1.98
Spherical aberrations (μm)	−0.152 ± 0.248
Postop spherical aberration change (μm)	−0.421 ± 0.160
Vertical coma Z(3,−1) (μm)	−0.253 ± 0.411
Horizontal coma Z(3,1) (μm)	0.088 ± 0.201
Vertical trefoil Z(3,−3) (μm)	0.022 ± 0.326
Horizontal trefoil Z(3,3) (μm)	−0.049 ± 0.095

with a decrease in postoperative visual acuity and impaired contrast sensitivity. Central presbyopic LASIK, first reported by Alió et al.,[18] is currently the most performed presbyopic LASIK technique worldwide and creates a central area for near vision and a peripheral area for distance vision. In peripheral presbyopic LASIK, the central cornea is dedicated to distance vision and the midperipheral cornea to near vision.[19,20]

This study used a central presbyopic LASIK procedure based on Q factor modulation in the nondominant eye. Q factor modulation, and in particular an increase in the negative Q factor (hyperprolateness), might improve depth of focus, which is useful for near vision. Postoperatively, patients showed good near and distance visual acuity with, a mean binocular UDVA of −0.04 ± 0.05 logMAR (20/20), a mean binocular UNVA of 0.1 ± 0.08 logMAR (J2), and a mean binocular UIVA of −0.13 ± 0.14 logMAR

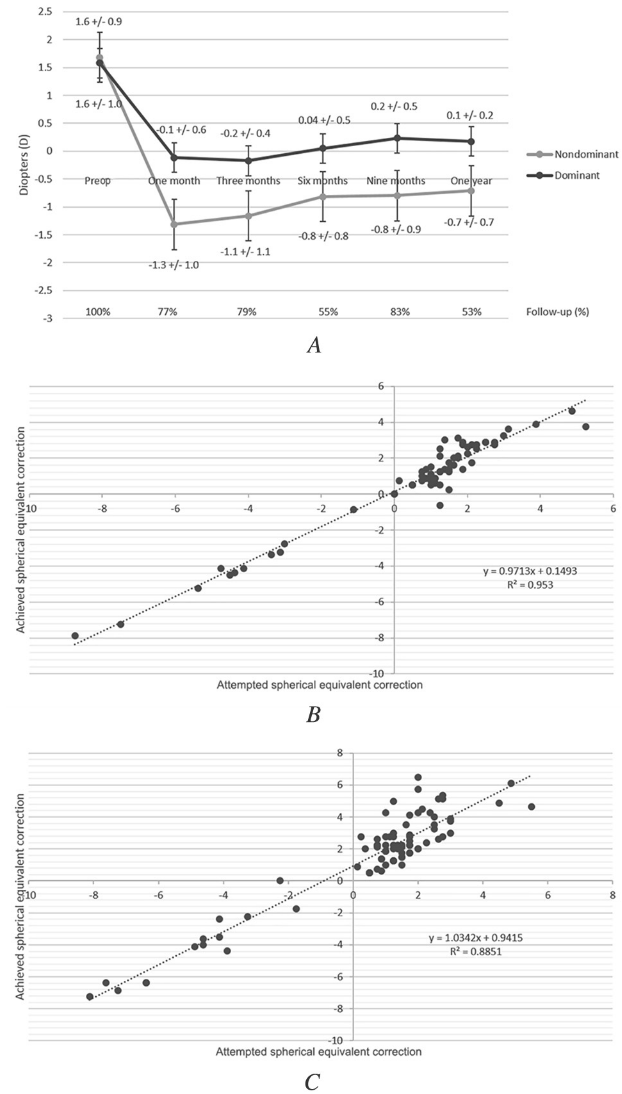


Figure 2. *A*: Spherical equivalent in dominant eyes and nondominant eyes. *B*: Achieved SE versus attempted SE in dominant eye. *C*: Achieved SE versus attempted SE in nondominant eye.

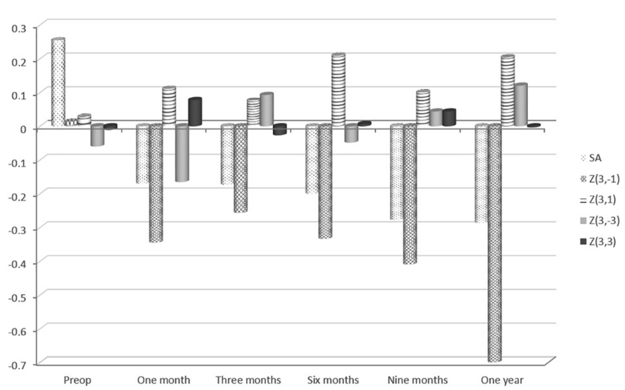


Figure 3. Higher-order aberrations (μm) in nondominant eye (SA = spherical aberrations; Z[3,–1] = vertical coma; Z[3,1] = horizontal coma; Z[3,–3] = vertical trefoil; Z[3,3] = horizontal trefoil).

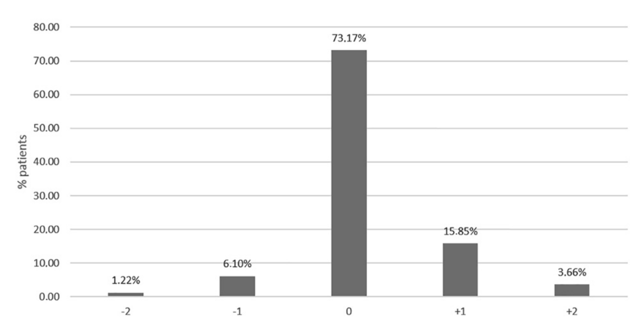
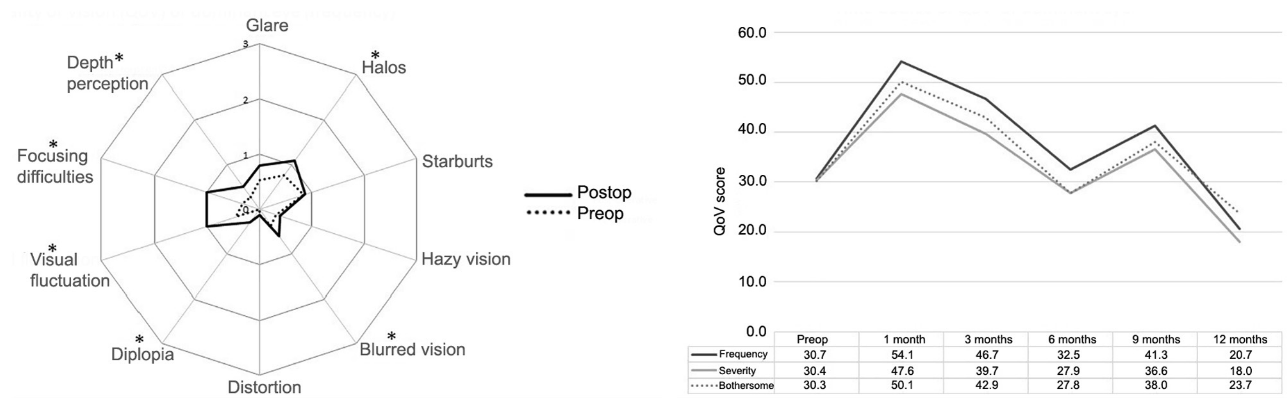


Figure 4. Line changes in CDVA (CDVA = corrected distance visual acuity).



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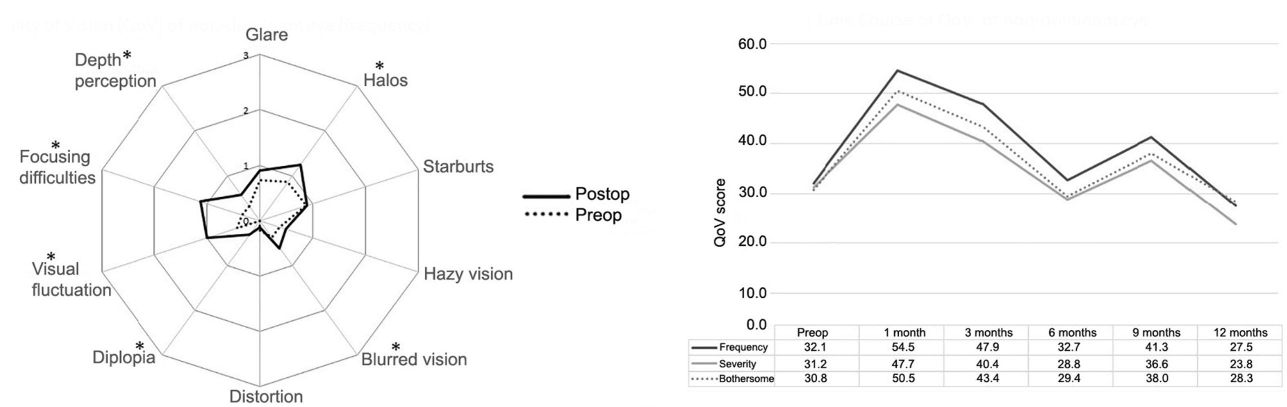

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Figure 5. *A*: Quality of Vision scores before and after surgery (frequency) (*top left*) and time course of quality of vision in dominant eyes (frequency subscale) (*top right*). *B*: Quality of Vision scores before and after surgery (frequency) (*bottom left*) and time course of quality of vision in nondominant eyes (frequency subscale) (*bottom right*) (* = statistically significant increase).

(20/16) at 1 year. One patient (1.22%) lost 2 or more lines of CDVA, which is consistent and even lower than results in other studies in which from 2% to 10% of patients lost 2 or more lines.[10,21,22] This shows the safety of this technique. Also, negative spherical aberrations and horizontal and vertical coma were induced in nondominant eyes by Q factor modulation, which is helpful for near vision, as shown by Nochez et al.[23]

A good correlation between the targeted Q factor and achieved Q factor was found (r = 0.260, P = .041) and confirms the predictability of this treatment. The Q factor and spherical aberrations were also correlated (r = 0.8, P < .0001), and we observed that near visual acuity was significantly better than preoperatively and was not associated with loss of distance visual acuity in patients with a targeted postoperative Q factor of −0.8.

Alarcon et al.[4] reported results in 50 eyes of 25 patients (mean age 49.6 years) treated with the Allegretto Wave EyeQ 400 Hz laser (Alcon Surgical, Inc.) with a Q factor modulation and monovision. The dominant-eye target was emmetropia, and the nondominant-eye target was an SE of −1.25 D with a Q factor of −1. More than 90% of patients reached a postoperative binocular distance and near uncorrected visual acuity of 0.0 logMAR. However, a significant decrease in contrast sensitivity and stereoacuity occurred in all patients. Gordon,[24] using the same laser platform, included 178 patients with a mean follow-up of 3 months; 81% patients reached a UDVA of 20/20 and 60% a UNVA of J2. No patient developed a complication, and there was no loss of corrected visual acuity or reports of glare or halos.

Results have also been reported with other correction algorithms or laser platforms. In a study by Alió et al.,[18] using an H. Eye Tech excimer laser platform (Technovision), 64% of patients obtained a UDVA of at least 20/20 and all patients a UNVA 20/40 or better at 6 months. Twelve percent of cases needed an enhancement procedure, and 72% of patients achieved spectacle independence at all distances. The authors concluded that central presbyopic LASIK might be used to improve functional near vision in patients with presbyopia associated with low and moderate hyperopia, although factors involved in the loss of spectacle-corrected visual acuity in some cases and a loss of vision quality should be further clarified before general use of the technique. Luger et al.[21] treated 66 eyes bilaterally using Presbymax software (Schwind eye-tech-solutions GmbH and Co. KG). At 1 year, 70% of patients achieved a UDVA of 0.1 logMAR or better, 84% patients obtained a UNVA of 0.1 logRAD or better, and 83% of eyes were within ±0.75 D of defocus. These results are consistent with those of Baudu et al.[25] who reported that 6 months postoperatively 76% of patients reached a UDVA of 0.1 logMAR or better, 91% of patients reached a UNVA of 0.1 logRAD, and 99% of patients were at ±1.0 D of defocus. Ryan and O'Keefe[26] and Abrieu-Lacaille et al.,[27] using a bilateral corneal multifocal treatment, reported a UDVA and UNVA of 0.15 logMAR and 0.18 logMAR, respectively, at 6 months. Jackson et al.,[22] using the Visx Star S4 platform (Abbott Medical Optics, Inc.), observed a visual acuity gain of 3 lines and 8 lines for UDVA and UNVA, respectively, with almost 100% patients with 20/23 J3 at 1 year after surgery. Reinstein et al.[10] treated 129 hyperopic and presbyopic patients with a nonlinear aspheric bilateral ablation profile with the Laser Blended Vision algorithm of the Mel 80 laser (Carl Zeiss Meditec AG). At 1 year, 95% reached a binocular UDVA of 20/25 or better and 81% achieved a UNVA of J2.

The results in this study are consistent with those in previous studies and confirm the efficacy of central presbyopic LASIK in presbyopia compensation. Moreover, 100% of patients reported satisfaction 9 months and 12 months postoperatively even though they reported increased halos, blurred vision, diplopia, and visual fluctuations. These visual side effects were more severe 1 month after surgery and then decreased to baseline 1 year after presbyopic LASIK. This could be explained by postsurgical ocular dryness and refraction evolution or neuroadaptation.[28]

In conclusion, the monovision correction algorithm proved to be a viable and valuable alternative in the treatment of presbyopia with LASIK surgery. Therefore, central presbyopic LASIK using Q factor modulation to increase depth of field by the Custom Q software using the Wavelight EX 500 wavefront-guided excimer laser seems to be a safe, accurate, and effective choice in presbyopia treatment.

WHAT WAS KNOWN

- In presbyopic LASIK surgery, some degree of monovision is usually added and anisometropia greater than 1.0 D is effective for improving visual acuity, depending on suppression of the blurred retinal image in the defocused eye.
- Anisometropia greater than 2.0 D can reduce intermediate visual acuity, contrast sensitivity, and depth perception.
- To overcome these limitations and increase the near visual acuity results, it has been proposed to use spherical aberration to increase depth of focus and minimize anisometropia with a nonlinear aspheric ablation profile.
- Presbyopic LASIK creates a multifocal corneal surface for correcting distance vision while simultaneously reducing the near spectacle dependency in presbyopic patients.
- Central presbyopic LASIK creates a central area for near vision and a peripheral area for distance vision.

WHAT THIS PAPER ADDS

- The Q factor modulation, and in particular an increase in the negative Q factor (hyperprolateness), improved depth of focus, which is useful for near vision.
- Negative spherical aberrations and horizontal and vertical coma were induced in nondominant eyes by Q factor modulation, which is helpful for near vision.
- Central presbyopic LASIK using the Q factor modulation to increase depth of field by the algorithm software using the wavefront-guided excimer laser was safe, accurate, and effective in treating presbyopia.

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