ORIGINAL ARTICLE

Wavefront Optimized *Versus* Custom-Q in Eyes with Myopia/Myopic Astigmatism Submitted to *LASER In Situ Keratomileusis*

Wavefront Optimized Versus Custom-Q em Olhos com Miopia/Astigmatismo Miópico Submetidos a *LASER In Situ Keratomileusis*

Catarina Castro [1], Diogo Rodrigues [1], Ana Carolina Abreu [1,2], Sílvia Monteiro [1,2], Maria do Céu Pinto [1,2]

[1] Department of Ophthalmology, Centro Hospitalar Universitário de Santo António, Porto, Portugal
[2] Department of Ophthalmology, Institute for the Biomedical Sciences Abel Salazar, University of Porto, Porto, Portugal

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ABSTRACT

INTRODUCTION: We aimed to compare the Custom-Q and Wavefront-optimized profiles in eyes with myopia or myopic astigmatism submitted to Femtosecond *LASER in situ* keratomileusis (LASIK).

METHODS: Retrospective study of eyes submitted to Femtosecond *LASER in situ* keratomileusis (LASIK) ablation for myopia or myopic astigmatism, with the Custom-Q and Wavefront Optimized profiles. Root mean square higher order aberrations, spherical aberration, 90º coma, 180º coma, and 0º trefoil were evaluated in the total and anterior cornea (Zernike Polynomial analysis, Pentacam HR®). Vision quality was assessed with the HD Analyzer® (Ocular Dispersion Index and Modular Transfer Function). All parameters were evaluated before and 1 and 6 months after surgery. For the Custom-Q group, the preoperative front mean 6 mm Q-value was used as the target.

RESULTS: Each group included 57 eyes of 30 patients. Both groups achieved similar good visual and refractive outcomes. One month after surgery, there was an increase in the root mean square higher order aberrations (p<0.001), without further changes (p>0.966). The spherical aberration increased in both groups at month 1 (p<0.018). There was a tendency for a superior increase of the spherical aberration in the Wavefront Optimized group at month 1 (p=0.083) and of the anterior 90º coma in the Custom-Q (p=0.084) group. However, the global variation (preoperative versus month 6) was similar for both aberrations (p=0.219 and p=0.632, respectively). There was an increase in the Q-value at month 1 in both groups (p<0.001), without differences between groups (p=0.105). The variation was similar in both groups, comparing the pre-operative values with month 6 (p=0.630). There were no significant changes in the Ocular Dispersion Index in the Custom-Q (p=0.304) and Wavefront-optimized groups (p=0.468). After correcting for baseline differences, there were no significant differences in the Modular Transfer Function values between groups (p>0.174).

CONCLUSION: Both profiles led to comparably good refractive and visual outcomes. The Custom-Q profile seems to show a tendency to induce less spherical aberration and more anterior 90º coma in the first month. However, the global variation after 6 months was similar between groups. The variation of the asphericity was similar between groups.

KEYWORDS: Astigmatism/surgery; Keratomileusis, Laser In Situ; Lasers, Excimer; Myopia/surgery; Refraction, Ocular.

RESUMO

INTRODUÇÃO: O objetivo do estudo foi comparar os perfis *Custom-Q e Wavefront Optimized* em olhos com miopia ou astigmatismo miópico submetidos a LASER *in situ keratomileusis* (LASIK) assistido por LASER Femtosegundo.

MÉTODOS: Estudo retrospectivo de olhos com miopia ou astigmatismo miópico submetidos a LASER *in situ keratomileusis* (LASIK) assistido por LASER Femtosegundo com os perfis *Custom-Q e Wavefront Optimized*. A *root mean square* das aberrações de alta ordem, aberração esférica, coma a 90º, coma a 180º e Trefoil a 0º, foram avaliados na córnea total e anterior (Polinómios de Zernike, Pentacam HR®). A qualidade da visão foi avaliada com o HD Analyzer® (Índice de Dispersão Ocular e Função de Transferência Modular). Os parâmetros foram avaliados antes e 1 e 6 meses após a cirurgia. No grupo Custom-Q, o Q médio pré-operatório aos 6 mm foi utilizado como objetivo.

RESULTADOS: Cada grupo incluiu 57 olhos de 30 pacientes. Ambos obtiveram resultados visuais e refrativos bons e semelhantes. Um mês após a cirurgia, houve aumento da root mean square das aberrações de alta ordem (p<0,001), sem alterações subsequentes (p>0,966). A aberração esférica aumentou em ambos os grupos ao primeiro mês (p<0,018). Houve uma tendência para um aumento superior da aberração esférica no grupo *Wavefront Optimized* no 1º mês (p=0,083) e do coma anterior a 90º no grupo do *Custom-Q* (p=0,084), mas a variação global (pré-operatório *versus* mês 6) foi semelhante (p=0,219 e p=0,632, respetivamente). Houve aumento do Q no 1º mês em ambos os grupos (p<0,001), sem diferenças entre eles (p=0,105). A variação do Q foi semelhante entre grupos comparando os valores pré-operatórios com o 6º mês (p=0,630). Não houve alterações significativas no Índice de Dispersão Ocular nos grupos *Custom-Q* (p=0,304) e *Wavefront Optimized* (p=0,468). Após correção das diferenças pré-operatórias, não houve diferenças nos valores da Função de Transferência Modular entre grupos (p>0,174).

CONCLUSÃO: Ambos os perfis levaram a resultados refrativos e visuais comparavelmente bons. O perfil Custom-Q parece mostrar tendência a induzir menos aberração esférica e mais coma anterior a 90º no 1º mês. Contudo, a variação global após 6 meses foi semelhante entre os grupos. A variação da asfericidade foi semelhante entre os grupos.

PALAVRAS-CHAVE: Astigmatismo/cirurgia; Lasers Excimer; Miopia/cirurgia; Queratomileuse Assistida por Excimer Laser In Situ; Refração Ocular.

INTRODUCTION

Myopia is a very common refractive error. In 2010 it was estimated that it affected around 1950 million people, with projections indicating that this value could increase to 4758 million people by 2050, affecting near 50% of the population.[1]

The eye has two main refractive structures, the cornea and the lens. Corneal refractive surgery is based on the change of the corneal curvature to compensate for the refractive error.[2] The anterior cornea is an aspheric surface, with the average cornea having a prolate shape. This means that the curvature of the cornea and, consequently, its refractive power, is higher in the center, decreasing towards the periphery. However, there is a significant variation among individuals, with the cornea' shape ranging from mild oblate to moderate prolate. To express the asphericity of the cornea, the Q-value was introduced.[2] The normal Q-value ranges from -0.88 (prolate) to +0.50 (oblate), with an average value around -0.25.[3]

Over the years, many surgical techniques were developed to correct refractive errors, with LASER in situ keratomileusis (LASIK) and photorefractive keratectomy (PRK) being the most used. In PRK, an excimer LASER ablation is performed after epithelial removal, while in LASIK, a thin corneal flap is performed before the stromal ablation with the excimer LASER.[4]

Despite the excellent visual and refractive outcomes, conventional LASER ablation procedures were also associated with an increase in higher-order aberrations (HOA) and asphericity and a decrease in visual quality.[5,6] To try to minimize this, aspheric ablation profiles were created, including the Wavefront-optimized (WFO) and the Custom-Q.

The WFO profile was designed to compensate for the HOA induced by the ablation, without changing the preexisting aberrations.[7] However, the asphericity value is not adjustable.[8] The Custom-Q profile is also an aspheric profile, but was designed to offer the ability to obtain a desired postoperative asphericity target.[9]

Our purpose is to compare the outcomes of WFO and Custom-Q profiles in eyes with myopia or myopic astigmatism submitted to Femtosecond LASER-assisted LASIK (FS-LASIK).

METHODS

This is a retrospective comparative study of eyes submitted to FS-LASIK with the WFO and Custom-Q ablation profiles in Centro Hospitalar Universitário de Santo António, a tertiary center in Porto, between August 2022 and February 2023.

The inclusion criteria for surgery were age over 21 years old, refractive stability for over 1 year, a spherical equivalent up to -7 diopters (D) and astigmatism up to -4 D, without ocular or systemic contraindications for the procedure. In this study, only eyes with myopia or myopic astigmatism were included. A thorough pre-operative evaluation was performed in all patients to assess the risk of ectasia. Eyes with a previous history of refractive surgery, with peri- or postoperative complications or that missed the postoperative appointments were excluded. Only eyes with at least 6 months of follow-up were included.

The FS-LASIK technique consisted of the creation of a superficial 110 μm thickness corneal flap with the Alcon Wavelight® FS200 Femtosecond LASER (Alcon®, Orlando, Florida), followed by stromal ablation with the EX500 Excimer LASER (Alcon®, Orlando, Florida). The flap was then repositioned. All treatments were performed by one of three experienced refractive surgeons who use a standardized technique. All eyes were treated with one of two treatment profiles: Custom-Q or WFO. The choice of treatment was randomized. The optic zone was 6.5 mm in all treatments. For both profiles, the pre-operative refraction, K1, K2, pachymetry at the thinnest point and pupillary diameter were inserted in the LASER settings. For the Custom-Q profile, the target asphericity was also inserted. The target asphericity considered was the pre-operative mean front Q-value in the 6 mm zone. The target refraction was emmetropia in all eyes. The K1, K2, pachymetry in the thinnest point, pupillary diameter and Q-value were obtained with the Pentacam HR® (Oculus, Optikgerate GmbH, Wetzlar, Germany).

All patients were evaluated at least before treatment, on the day after surgery, 1 month and 6 months after treatment. For this study, only the preoperative, month 1 and month 6 evaluations were analyzed. The uncorrected- (UCVA) and best-corrected (BCVA) visual acuity were evaluated in the Snellen scale and converted to LogMAR for statistical purposes.[10] The HOA, namely, the Root Mean Square HOA (RMS HOA), the spherical aberration (SA), the 90º coma, the 0º coma and 0º trefoil, were evaluated in the total cornea and anterior surface, with the Zernike Polynomial analysis (Pentacam HR®, Oculus, Optikgerate GmbH, Wetzlar, Germany). The corneal asphericity (Q-value) was also evaluated with the Pentacam HR®. Vision quality was assessed with the Ocular Dispersion Index (OSI) and Modular Transfer Function (MTF), evaluated with the HD Analyzer™ (Visiometrics S.L., Terrassa, Spain). The demographic data (age and gender), manifest spherical equivalent (SE), depth of ablation (μm), and preoperative K1 and K2 were also recorded.

A subanalysis was performed in eyes with a preoperative SE ≤-4 D, to evaluate the differences between groups in cases of higher refractive errors.

This study complied with the ethical requirements of Centro Hospitalar Universitário de Santo António and was performed following the tenets of the Declaration of Helsinki in its latest amendment.

Statistical analysis was performed using IBM® SPSS® Statistics version 26. The normality of data was assessed using the Kolmogorov-Smirnov test. For continuous variables with normal distribution, descriptive statistics are shown as mean ± standard deviation. For continuous variables with skewed distribution, descriptive statistics are shown as median [range]. For categorical variables, descriptive statistics are shown as absolute and relative frequencies. For comparison between groups, independent sample t-tests were used after confirmation of normal distribution and homogeneity of variances, and Mann-Whitney U tests were used in the presence of a skewed distribution. For evaluation of changes over time, parametric and non-parametric tests were used appropriately. To correct for baseline differences, a one-way ANCOVA was used. Post-hoc Bonferroni corrections were applied. Statistical significance was considered in the presence of a *p*-value inferior to 0.05.

RESULTS

This study included 114 eyes of 60 patients. The Custom-Q group included 57 eyes of 30 patients and the WFO group included 57 eyes of 30 patients. Except for the MTF (p=0.025) there were no other significant differences at baseline between both groups. Baseline characteristics are detailed in Table 1.

In the Custom-Q group, 20 eyes (35%) had a SE ≤-4 D and in the WFO group, 24 eyes (42%) had a SE ≤-4 D. There were no differences in the pre-operative age, gender, SE, Q-value or HOA between the two subgroups (p>0.125).

VISUAL AND REFRACTIVE OUTCOMES

The UCVA was 0.00 [-0.10 – 0.20] in the Custom-Q group and 0.00 [-0.10 – 0.22] in the WFO group, both at month 1 and month 6, without statistically significant differences between groups at both timepoints (p=0.843 and p=0.763, respectively). The BCVA was 0.00 [-0.10 – 0.10] in the Custom-Q group and 0.00 [-0.10 – 0.22] in the WFO group, at month 1 and month 6, without differences between groups at both timepoints (p=0.974 and p=0.892, respectively).

At month 1, the SE was 0.00 ± 0.00 D in the Custom-Q group and -0.02 ± 0.12 D in the WFO group (p=0.163). At month 6, the SE remained unchanged (0.00 ± 0.00 D and -0.02 ± 0.12 D, respectively, p=0.184). All eyes achieved a SE within ±0.25 D, except for two eyes in the WFO group (-0.5 D and -0.75D).

Table 1. Baseline characteristics.

	Custom-Q	WFO	*p*-value
Gender, female, n (%)	15 (50%)	15 (50%)	0.999
Age, years, mean±SD	32±7	31±4	0.749
BCVA, LogMAR, median [range]	0.00 [0.00 – 0.22]	0.00 [0.00 – 0.20]	0.081
SE, D, mean±SD	-3.6±1.4	-3.4±1.9	0.382
Sphere, D, median [range]	-3.1 [-6.50 – -1.00]	-2.7 [-6.25 - -0.00]	0.262
Cylinder, D, median [range]	-0.75 [-3.00 – 0.00]	-1.00 [-3.50 – 0.00]	0.371
Q-value, mean±SD	-0.22±0.10	-0.22±0.12	0.945
Paquimetry, µm, mean±SD	568±26	566±28	0.696
K1, D, mean±SD	42±1.5	42±1.7	0.655
K2, D, mean±SD	44±1.5	44±1.7	0.711
OSI, median [range]	0.9 [0.2-8.5]	0.8 [0.3 – 7.5]	0.076
MTF, mean±SD	29±13	34±10	0.025
RMS HOA total cornea, median [range]	0.295 [0.176 – 0.703]	0.325 [0.179 – 0.747]	0.175
RMS HOA anterior cornea, median [range]	0.324 [0.190 – 0.694]	0.368 [0.006 – 0.436]	0.335
Spherical aberration total cornea, median [range]	0.152 [0.016 – 0.354]	0.154 [0.006 – 0.436]	0.496
Spherical aberration anterior cornea, median [range]	0.216 [0.059 – 0.395]	0.206 [0.070 – 0.490]	0.932
90º coma total cornea, median [range]	-0.018 [-0.209 – 0.299]	-0.007 [-0.349 – 0.520]	0.428
90º coma anterior cornea, median [range]	0.011 [-0.222 – 0.377]	0.013 [-0.335 – 0.657]	0.584
0º coma total cornea, mean±SD	0.000±0.108	0.007±0.142	0.778
0º coma anterior cornea, mean±SD	-0.004±0.112	0.004±0.005	0.757
Trefoil total cornea, median [range]	-0.001 [-0.219 - 0.197]	0.002 [-0.098 – 0.161]	0.433
Trefoil anterior cornea, median [range]	-0.009 [-0.187 – 0.161]	0.001 [-0.135 - 0150]	0.707

WFO – wavefront optimized; SD – standard deviation; BCVA – best-corrected visual acuity; SE – spherical equivalent; D – diopters; OSI – Ocular Dispersion Index; MTF – modular transfer function; RMS HOA – root mean square higher order aberrations

NOTE: Statistically significant values are highlighted in bold.

HIGHER ORDER ABERRATIONS

The changes in the HOA are summarized in Tables 2, 3 and 4.

At month 1, there was a significant positive and similar (*p*=0.665) increase of the RMS HOA in the total and anterior cornea in both groups (*p*<0.001). There were no further changes at month 6 (*p*>0.966).

The SA increased in both groups at month 1 (*p*<0.018). There was a tendency for a significant increase in the SA in the WFO group at month 1 (*p*=0.083). The global variation from the

Table 2. Variation of HOA and asphericity in the Custom-Q group.

	Preoperative	Month 1	Month 6	*p*-value
Q-value, mean±SD	-0.22 ± 0.10	0.54 ± 0.42	0.39 ± 0.40	**<0.001**
RMS HOA total cornea, median [range]	0.295 [0.176 – 0.703]	0.470 [0.242 – 1.050]	0.502 [0.244 – 1.185]	**<0.001**
RMS HOA anterior cornea, median [range]	0.324 [0.190 – 0.694]	0.510 [0.224 – 1.039]	0.525 [0.279 – 1.179]	**<0.001**
Spherical aberration total cornea, median [range]	0.152 [0.016 – 0.354]	0.189 [0.004 – 0.539]	0.185 [-0.008 – 0.541]	**0.047**
Spherical aberration anterior cornea, median [range]	0.216 [0.059 – 0.395]	0.263 [0.077 – 0.606]	0.269 [0.100 – 0.611]	**0.038**
90º coma total cornea, median [range]	-0.018 [-0.209 – 0.299]	-0.099 [-0.840 – 0.483]	-0.136 [-0.963 – 0.388]	**0.005**
90º coma anterior cornea, median [range]	0.011 [-0.222 – 0.377]	-0.066 [-0.770 – 0.517]	-0.102 [-0.886 – 0.409]	**0.001**
0º coma total cornea, mean±SD	0.000±0.108	0.025 ± 0.171	0.040 ± 0.130	0.153
0º coma anterior cornea, mean±SD	-0.004±0.112	0.025 ± 0.107	0.039 ± 0.144	0.091
Trefoil total cornea, median [range]	-0.001 [-0.219 - 0.197]	-0.008 [-0.179 – 0.385]	-0.001 [-0.236 – 0.304]	0.714
Trefoil anterior cornea, median [range]	-0.009 [-0.187 – 0.161]	0.003 [-0.173 – 0.467]	0.000 [-0.2421 – 0.242]	0.112

SD – standard deviation; RMS HOA – root mean square higher order aberrations; OSI – Ocular Dispersion Index; MTF – modular transfer function

NOTE: Statistically significant values are highlighted in bold.

Table 3. Variation of HOA and asphericity in the WFO group.

	Preoperative	Month 1	Month 6	*p*-value
Q-value, mean±SD	-0.22 ± 0.12	0.39 ± 0.49	0.35 ± 0.44	**<0.001**
RMS HOA total cornea, median [range]	0.325 [0.179 – 0.747]	0.0.503 [0.238 – 0.982]	0.503 [0.238 – 1.608]	**<0.001**
RMS HOA anterior cornea, median [range]	0.368 [0.006 – 0.436]	0.558 [0.210 – 1.142]	0.559 [0.226 – 1.581]	**<0.001**
Spherical aberration total cornea, median [range]	0.154 [0.006 – 0.436]	0.253 [-0.045 – 0.631]	0.247 [-0.043 – 0.643]	**<0.001**
Spherical aberration anterior cornea, median [range]	0.206 [0.070 – 0.490]	0.324 [0.018 – 0.699]	0.330 [0.017 – 0.719]	**<0.001**
90º coma total cornea, median [range]	-0.007 [-0.349 – 0.520]	-0.082 [-0.819 – 0.813]	-0.101 [-0.809 – 0.440]	**0.024**
90º coma anterior cornea, median [range]	0.013 [-0.335 – 0.657]	-0.029 [-0.726 – 0.982]	-0.076 [-0.746 – 0.544]	**0.004**
0º coma total cornea, mean±SD	0.007 ± 0.142	0.008 ± 0.168	0.028 ± 0.190	0.913
0º coma anterior cornea, mean±SD	0.004 ± 0.005	0.008 ± 0.179	0.029 ± 0.199	0.959
Trefoil total cornea, median [range]	0.002 [-0.098 – 0.161]	0.020 [-0.259 – 0.325]	0.012 [-0.368 – 1.358]	0.700
Trefoil anterior cornea, median [range]	0.001 [-0.135 - 0150]	0.503 [0.238 – 1.608]	-0.001 [-0.349 – 1.290]	0.277

WFO – wavefront optimized; RMS HOA – root mean square higher order aberrations; SD – standard deviation; OSI – Ocular Dispersion Index; MTF – modular transfer function.

NOTE: Statistically significant values are highlighted in bold.

Table 4. Variations in the higher order aberrations.

		p-value change over time*	Preoperative *vs* Month 1	*p*-value[1]	Month 1 *vs* Month 6	*p*-value[1]	Preoperative *vs* Month 6	*p*-value[1]
RMS HOA total cornea	**Custom-Q**	**<0.001**	+0.146 [-0.060 – 0.720], ***p*<0.001**	0.665	+0.014 [-0.260 – 0.140], *p*=0.999	0.731	+0.168 [-0.110 – 0.850], **p<0.001**	0.834
	WFO	**<0.001**	+0.152 [-0.160 – 0.062], ***p*<0.001**		+0.021 [-0.230 – 0.630], *p*=0.966		+0.171 [-0.230 – 1.060], **p<0.001**	
RMS HOA anterior cornea	**Custom-Q**	**<0.001**	+0.124 [-0.070 – 0.660], ***p*<0.001**	0.790	+0.002 [-0.360 – 0.630], *p*=0.999	0.789	+0.171 [-0.08 – 0.730], *p*=0.582	0.918
	WFO	**<0.001**	+0.137 [-0.170 – 0.640], ***p*<0.001**		+0.018 [-0.240 – 0.440], *p*=0.999		+0.147 [-0.240 – 0.870], *p*=0.864	
Spherical aberration total cornea	**Custom-Q**	**0.047**	+0.026 [-0.150 – 0.410], ***p*=0.018**	0.083	+0.007 [-0.250 – 0.230], *p*=0.999	0.086	+0.045 [-0.160 – 0.350], ***p*=0.018**	0.219
	WFO	**<0.001**	+0.072 [-0.230-0.480], ***p*<0.001**		-0.002 [-0.220 – 0.300], *p*=0.582		+0.065 [-0.230 – 0.470], ***p*<0.001**	
Spherical aberration anterior cornea	**Custom-Q**	**0.038**	+0.037 [-0.140 – 0.430], ***p*=0.003**	0.118	+0.012 [-0.250 – 0.230], *p*=0.741	0.130	+0.050 [-0.140 – 0.380], ***p*=0.006**	0.248
	WFO	**<0.001**	+0.067 [-0.190 – 0.500], ***p*<0.001**		-0.006 [-0.220 – 0.290], *p*=0.864		+0.073 [-0.190 – 0.500], ***p*<0.001**	
90º coma total cornea	**Custom-Q**	**0.005**	-0.101 [-0.960 – 0.480], ***p*=0.006**	0.117	-0.009 [-0.480 – 0.200], *p*=0.576	0.257	-0.116 [-1.080 – 0.390], ***p*=0.027**	0.721
	WFO	**0.024**	-0.035 [-0.700 – 0.470], *p*=0.528		-0.052 [-0.730-0.280], ***p*=0.042**		-0.084 [-0.760 – 0.400], ***p*=0.018**	
90º coma anterior cornea	**Custom-Q**	**0.001**	-0.091 [-0.970 – 0.490], ***p*=0.006**	0.084	-0.016 [-0.490 – 0.200], *p*=0.138	0.405	-0.116 [-1.090 – 0.380], ***p*=0.018**	0.632
	WFO	**0.004**	-0.039 [-0.064 – 0.480], *p*=0.744		-0.047 [-0.700 – 0.280], ***p*=0.030**		-0.094 [0.730 – 0.400], ***p*=0.024**	
0º coma total cornea	**Custom-Q**	0.153	0.022 ± 0.124	-	+0.017 ± 0.072	-	+0.037 ± 0.122	-
	WFO	0.913	0.001 ± 0.170		+0.009 ± 0.080		+0.021 ± 0.177	
0º coma anterior cornea	**Custom-Q**	0.091	0.026 ± 0.125	-	+0.016 ± 0.072	-	0.040 ± 0.124	-
	WFO	0.959	0.004 ± 0.170		+0.010 ± 0.077		0.024 ± 0.177	
Trefoil total cornea	**Custom-Q**	0.714	-0.008 [-0.170 – 0.540]	-	-0.017 [-0.620 – 0.170]	-	-0.017 [-0.620 – 0.170]	-
	WFO	0.700	+0.011 [-0.210 – 0.160]		-0.004 [-0.310 – 1.130]		-0.004 [-0.310 – 1.130]	
Trefoil anterior cornea	**Custom-Q**	0.112	+0.021 [-0.180 – 0.520]	-	-0.014 [-0.680 – 0.170]	-	+0.005 [-0.180 – 0.210]	-
	WFO	0.277	+0.029 [-0.200 – 0.170]		-0.016 [-0.320 – 1.000]		+0.012 [-0.340 – 1.160]	

NOTE: Values are either presented as median [range] or mean ± standard deviation. Statistically significant values are highlighted in bold.
RMS HOA – root mean square higher order aberrations; SD – standard deviation; WFO – wavefront optimized.
* In cases where the *p*-value for variation over time was >0.05, no further comparisons between timepoints were performed.
[1] Comparison of the variation between Custom-Q and WFO.

preoperative to month 6 was similar between groups (p=0.219).

The Custom-Q group tended to have a slightly superior negative increase in the anterior 90º coma at month 1 compared with the WFO group (p=0.084). The global variation from the preoperative to month 6 was similar between groups (p=0.632).

Table 5. **Variation in the asphericity.**

	Variation over time, *p*-value	Preoperative *vs* Month 1	*p*-value[1]	Month 1 *vs* Month 6	*p*-value[1]	Preoperative *vs* Month 1	*p*-value[1]
Custom-Q	<0.001	+0.75 ± 0.41, ***p*<0.001**	0.105	-0.12 ± 0.29, ***p*=0.022**	**0.040**	+0.61 ± 0.40, ***p*<0.001**	0.630
WFO	<0.001	+0.60 ± 0.50, ***p*<0.001**		-0.02 ± 0.12, *p*=0.425		+0.57 ± 0.46, ***p*<0.001**	

NOTE: Values are presented as mean ± standard deviation. Statistically significant values are highlighted in bold.

WFO – wavefront optimized.

[1] Comparison of the variation between Custom Q and WFO.

There were no changes in the 0º coma and trefoil (*p*>0.091).

When considering only eyes with a preoperative SE more myopic than - 4D, there were no differences in the variation of all evaluated aberrations from the preoperative to month 6 (*p*>0.318).

ASPHERICITY

There was a statistically significant increase in the Q-value at month 1 in both groups (*p*<0.001), without differences between groups (*p*=0.105). At month 6, there was a slight decrease in the Q-value in the Custom-Q group (*p*=0.022), but overall, the variation was similar in both groups, comparing the pre-operative values with month 6 (*p*=0.630). Changes in the asphericity are detailed in Tables 2, 3 and 5.

When considering only eyes with a SE more myopic than - 4D, there were no differences in the variation of the Q-value from the preoperative to the 6-month visit (+0.86 ± 0.55 in the Custom-Q *vs* +0.99 ± 0.28 in the WFO group, *p*= 0.973).

VISION QUALITY

There were no statistically significant changes in the OSI over time in the Custom-Q group (p=0.304) and in the WFO group (*p*=0.468). Regarding the MTF, there was an increase from the preoperative values to Month 6 (*p*=0.007) in the Custom-Q Group. There was a tendency for an increase in the MTF in the WFO group (*p*=0.051). After correcting for baseline differences, there were no statistically significant differences in the MTF values at month 1 (*p*=0.174) and month 6 (*p*=0.942) between groups. The changes in these parameters are detailed in Table 6.

ABLATION DEPTH

There were no differences in the ablation depth between the Custom-Q and the WFO ablation profile (64 [28 -111] µm *vs* 58 [13 - 111] µm, *p*=0.165).

DISCUSSION

Ever since the LASER refractive surgery was introduced, there has been a continuous technological improvement. At the beginning of photoablation, the objective was to obtain predictable and stable results.[11] The standard ablation procedures were based in the removal of convex-concave tissue lenticules with spherocylindrical surfaces and were associated with a significant decrease in vision quality, especially in mesopic and low-contrast situations.[2] Myopic correction with an excimer photoablation is obtained by the removal of central corneal tissue, which causes changes in the cornea's asphericity, leading to a more oblate shape (higher Q-values).[12] Previous studies have also shown that after LASIK and PRK, there is an increase in the presence of HOA, in particular the SA, which causes night vision disturbances, such as haloes, glare and starbursts.[13–17] There is, additionally, an association between the cornea´s asphericity and the presence of SA.[18] Lower Q-values are associated with less SA, with the minimum SA obtained with a Q-value around -0.40.[18] Hence, the increase in the SA and other HOA observed after corneal ablation procedures may be due to the changes in the cornea's asphericity.[19] This, among other factors, contributes to the loss of vision quality observed in patients submitted to corneal refractive surgery.[12,13]

Table 6. **Variation of the vision quality parameters.**

		Variation over time*, *p*-value	Preoperative	Month 1	*p*-value	Month 6	*p*-value Month 1 *vs* Month 6	*p*-value Preoperative *vs* Month 6
OSI	Custom Q	0.304	0.9 [0.2-8.5]	0.9 [0.3 – 3.3]	-	0.8 [0.4 – 3.3]	-	-
	WFO	0.468	0.8 [0.3 – 7.5]	0.7 [0.3 – 4.0]	-	0.7 [0.3 – 3.8]	-	-
MTF	Custom Q	**0.005**	29 ± 13	34 ± 12	0.172	35 ± 10	0.547	**0.007**
	WFO	0.051	34 ± 10	38 ± 9	-	37 ± 10	-	-

NOTE: values are either presented as median [range] or mean ± standard deviation; WFO – wavefront optimized; OSI – Ocular Dispersion Index; MTF – modular transfer function.

* In cases were the *p*-value for variation over time was >0.05 no further comparisons between timepoints were performed.

NOTE: statistically significant values are highlighted in bold.

To try to solve the vision quality problems generated after standard LASER ablations, the aspheric ablation profiles were created.[2] Wavefront-guided profiles customize the treatment based on the higher and lower order aberrations unique to the eye that is being treated.[20] Previous studies have shown some superiority of wavefront-guided treatments in comparison to the WFO profile.[20–22] Nonetheless, this analysis is time-consuming and not necessary for most patients.[2]

The WFO profile takes into consideration some variables of the eye being treated but uses a pre-programmed ablation profile based on a populational analysis. As previously mentioned, this profile was designed to compensate for the HOA induced by the treatment, without changing the pre-existing ones.[20] In myopic correction, the WFO profile significantly increases the depth of ablation in the mid-periphery of the optical zone, compared to the standard ablation profiles. This helps to preserve the normal corneal prolateness but does not aim to maintain the asphericity.[9] The Custom-Q profile, in turn, allows the setting of a target Q-value and aims to change the mean asphericity by symmetrically adjusting the number of mid-peripheral LASER pulses.[8] Thus, both treatment profiles work by modifying the ablation at the mid-periphery, but through different strategies.[9] The two treatment profiles also diverge in other aspects. The WFO profile does not take into consideration the preoperative K's and treats sphere and cylinder sequentially. The adjustments of sphere and cylinder are in 0.25 D steps, the adjustments in the optical zone are in 0.5 mm steps and there is no adjustment of the transition zone (automatic) or the target Q-value. On the other side, the Custom-Q profile takes the pre-operative K's and Q-value into account and treats sphere and cylinder simultaneously. The adjustments of sphere and cylinder are finer (0.01 D steps). There is also a finer adjustment of the optical zone (0.1 mm steps) and of the transition zone (0.05 mm steps).[23]

In our study, the SA increased in both groups, but there was a tendency for a greater increase in the WFO group at month 1. This could suggest a better performance of the Custom-Q profile in terms of SA induction due to greater customization of the treatment. However, this difference seemed to fade over time, with a similar variation after 6 months. The anterior 90º coma, in turn, showed a tendency for a superior increase in the Custom-Q group at month 1, but this also faded over time. The different ways in which the ablations are performed may explain the different tendencies in HOA induction between groups. However, the corneal healing process and the biomechanical adjustment seem to minimize the differences over time.

The fact that the variation of the Q-value was not different between groups suggests that using the pre-operative Q-value, as recommended by the manufacturer, may not be adequate to maintain the prolacity of the cornea. In fact, González-Cruces[24] *et al* used two different Q-values in their study and found that when the target Q-value was defined as -0.6 the Custom-Q group had lower SA than the WFO group. Nonetheless, no differences were found when the preoperative Q-value was used, as in our study.[24] These findings seem to be further evidence that more negative target Q-values are needed to obtain lower HOA induction with the Custom-Q profile. We only used the preoperative Q-value as the target Q in the Custom-Q group. In future studies, it would be interesting to see the outcomes of defining a more negative Q-value, closer to the ideal value (-0.40), to better understand the potential differences between the two profiles.

Other previous studies have compared the WFO and Custom-Q treatment profiles in eyes submitted to LASIK, with varying results. Overall, as in our study, all studies suggest that both ablation profiles lead to good visual and refractive outcomes.[8,9,24,25] However, Mostafa *et al*[9] found a better UCVA and BCVA in the WFO group. Of note, in this study, the preoperative UCVA and BCVA were already better in the WFO group.[9]

Similar to our results, Mostafa *et al*[9] found a similar oblate shift between both groups. However, it is important to note that, in this study, the spherical equivalent was more myopic in the Custom-Q group and the optical zone was inferior, leading to more ablated tissue.[9] Tawfik *et al*,[8] also found that both groups had an oblate shift after treatment, however, contrary to our results, the postoperative Q-value was less positive in the Custom-Q group.[8] Stojanovik *et al*[25] also found that the postoperative Q-value was inferior in the Custom-Q group. All discussed studies showed an oblate shift after LASIK with both profiles.[8,9,24,25] A possible explanation, offered by Koller *et al*,[2] to this oblate shift that still happens with the aspheric ablation profiles, despite the fact that they are designed to maintain the prolacity, is that it is a consequence of the structural response of the cornea, which is biomechanically weakened by the LASIK.[2]

Regarding the HOA, as in our study, Mostafa *et al*[9] found an increase in the presence of the RMS HOA, similar between groups. Stojanovik *et al*[25] also did not find differences in the postoperative HOA.

Concerning visual quality, there were no changes in the OSI score after both procedures. The MTF significantly increased after the Custom-Q procedure. Nevertheless, despite not reaching statistical significance, there was also a tendency for an increase in the WFO group. It is important to note, however, that after correcting for baseline differences, there were no statistically significant differences in the postoperative MTF between groups. Therefore, both procedures seem to lead to similar visual quality outcomes. This shows that the aspherical ablation profiles are successful in preventing the worsening of visual quality. Stojanovik *et al*[25] did not find differences in the low-contrast visual acuity between groups. However, to our best knowledge, no other study has evaluated the OSI and MTF in these patients.

Our study has some limitations, in particular the retrospective design, the small number of participants and the short follow-up period. We also did not evaluate the ablation centering and the angle Kappa, which may influence the HOA induction, in particular the coma. Finally, we only used the preoperative Q-value as the target value. Regardless of these limitations, our study also has several strengths, such as having similar groups, both in size and in the baseline characteristics, allowing for more reliable comparisons. Furthermore, most studies only assess the RMS HOA and the SA, without evaluating the other HOA, and do not assess quality vision, as assessed in our study.

In conclusion, in our study, the outcomes between the WFO and Custom-Q profiles were comparable and both profiles seem to lead to great refractive and visual outcomes. Both profiles seem to induce similar HOA. The Custom-Q profile seems to induce less SA in the first month, but a larger sample of patients is needed to validate these differences. Besides the ones described, other ablation profiles are available, and a universal optimal treatment profile is yet to be established.[11] Furthermore, the existing studies have conflicting outcomes, hence, future prospective comparative studies with larger samples are needed to further clarify the differences between both ablation profiles.

CONTRIBUTORSHIP STATEMENT / DECLARAÇÃO DE CONTRIBUIÇÃO

CC: Design, data acquisition, analysis, and interpretation; writing.

DR: Design, data acquisition, analysis, and interpretation.

ACA, SM, and MCP: Design, data acquisition, analysis, and interpretation; review.

All authors approved the final version to be published.

CC: Desenho, aquisição, análise e interpretação de dados; redação.

DR: Desenho, aquisição, análise e interpretação de dados.

ACA, SM e MCP: Desenho, aquisição, análise e interpretação de dados; revisão.

Todos os autores aprovaram a versão final a ser publicada.

All authors participated in the conceptualization of this work. Catarina Castro and Diogo Rodrigues participated in the data acquisition. All authors participated in the analysis and interpretation of the data. Catarina Castro wrote the original draft. All authors revised and approved the final draft. All authors accept to be held accountable for the contents of this work.

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Corresponding Author/
Autor Correspondente:

Catarina Castro
Department of Ophthalmology,
Centro Hospitalar Universitário de Santo António, Largo do Prof. Abel Salazar, 4099-001 Porto, Portugal
E-mail: catarinamscastro@gmail.com

ORCID: 0000-0002-7707-7861