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• Clinical Research •

Comparative analysis of the efficacy of astigmatic correction after wavefront-guided and wavefront-optimized LASIK in low and moderate myopic eyes

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Abstract

• AIM: To evaluate and compare the efficacy of the astigmatic correction achieved with laser *in situ* keratomileusis (LASIK) in eyes with myopic astigmatism using wavefront-guided (WFG) and wavefront-optimized (WFO) ablation profiles.

• METHODS: Prospective study included 221 eyes undergoing LASIK: 99 and 122 eyes with low and moderate myopic astigmatism (low and moderate myopia groups). Two subgroups were differentiated in each group according to the ablation profile: WFG subgroup, 109 eyes (45/64, low/moderate myopia groups) treated using the Advanced CustomVue platform (Abbott Medical Optics Inc.), and WFO subgroup, 112 eyes (54/58, low/moderate myopia groups) treated using the EX-500 platform (Alcon). Clinical outcomes were evaluated during a 6-month follow-up, including a vector analysis of astigmatic changes.

• RESULTS: Significantly better postoperative uncorrected visual acuity and efficacy index was found in the WFG subgroups of each group (*P*≤0.041). Postoperative spherical equivalent and cylinder were significantly higher in WFO subgroups (*P*≤0.003). In moderate myopia group, a higher percentage of eyes with a postoperative cylinder ≤0.25 D was found in the WFG subgroup (90.6% *vs* 65.5%, *P*=0.002). In low and moderate myopia groups, the difference vector was significantly higher in the WFO subgroup compared to WFG (*P*<0.001). In moderate myopia group, the magnitude (*P*=0.008) and angle of error (*P*<0.001) were also significantly higher in the WFO subgroup. Significantly less induction of high order aberrations were found with WFG treatments in both low and moderate myopia groups (*P*≤0.006).

• CONCLUSION: A more efficacious correction of myopic astigmatism providing a better visual outcome is achieved with WFG LASIK compared to WFO LASIK.

• KEYWORDS: myopia; wavefront-guided LASIK; wavefront-optimized LASIK; astigmatism
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INTRODUCTION

Laser *in situ* keratomileusis (LASIK) has demonstrated to be a safe and efficacious technique for the correction of different levels of ocular astigmatism[1-12]. Two types of ablation profiles can be used in LASIK for such purpose: wavefront-optimized (WFO) and wavefront-guided (WFG) ablation[13]. The aim of WFO algorithms is to minimize the induction of spherical aberration (SA) through an approach based on refraction and keratometry (aspheric profile)[13]. WFG profiles are designed according to the preoperative magnitude of low and high order aberrations (HOAs), providing a customized correction of the optical errors of the eye and maximizing the postoperative level of visual quality[13]. WFO algorithms are incorporated as a default option in most of currently available excimer laser platforms. However, WFG ablation profiles are calculated based on the ocular aberrometric and corneal topographic data obtained by the clinician in the preoperative examination. These data must be exported and uploaded to the excimer laser computer for their management, being a more time-consuming procedure[13].

Some studies have evaluated the potential benefit of WFG LASIK treatments over WFO for the correction of astigmatism[2,10,12]. Toy *et al*[2] compared the outcomes of WFO and WFG LASIK using the Alcon WaveLight Allegretto Eye-Q 400-Hz excimer laser platform and found that the WFG profile provided more predictable astigmatic corrections in eyes with

myopia and astigmatism. Specifically, these authors found that the angle of error (AE) of the astigmatic treatment was 80% less with the WFG ablation profile compared to the WFO option[2]. In contrast, He *et al*[14] did not find significant differences in the level of residual astigmatism among a group of eyes with myopic astigmatism treated with WFG LASIK using the Abbott Medical Optics (AMO) Visx CustomVue S4IR excimer laser and another group of eyes treated with WFO LASIK using the Alcon WaveLight Allegretto Eye-Q 400-Hz excimer laser. In another study, Taneri *et al*[10] only obtained significant differences in terms of HOA correction between myopic eyes undergoing WFG and WFO LASIK using the Technolas Perfect Vision Zyoptix platform. Frings *et al*[6] found that the most limited correction of astigmatism with LASIK was present for cylinders of 0.50 D or less as they are commonly overcorrected.

The purpose of the current study was to evaluate and compare the clinical outcomes in eyes with low to moderate myopic astigmatism as well as the efficacy of the astigmatic correction evaluated by vector analysis after LASIK using WFG (Advanced CustomVue; AMO Inc., Santa Ana, CA, USA) and WFO (EX-500 platform, Alcon, Fortworth, Texas, USA) ablation profiles.

SUBJECTS AND METHODS

Subjects A prospective, consecutive, comparative, and masked clinical trial was performed at Horus Vision Correction Centre (HVCC) to evaluate the visual and aberrometric outcomes of LASIK in 221 eyes with myopic astigmatism. Two groups were differentiated according to the magnitude of the spherical equivalent (SE) treated: low (from -0.50 to -3.00 D) (99 eyes) and moderate (from -3.01 to -6.00 D) myopia (122 eyes) groups. Likewise, each group was subdivided into two subgroups according to the ablation profile used for the treatment: WFG subgroup including 109 eyes (45 low myopia *vs* 64 moderate myopia) treated using a WFG ablation profile (Advanced CustomVue platform, AMO Inc.), and WFO subgroup including 112 eyes (54 low myopia *vs* 58 moderate myopia) treated using a WFO profile (EX-500 platform, Allegretto Q-500 excimer laser, Alcon).

Inclusion criteria for the study were patients with myopia and/or myopic astigmatism, SE of -6.00 D or below, patients requiring spectacle independence and seeking for a laser refractive surgery solution, and no previous ocular surgery or active ocular disease. Exclusion criteria were myopic SE of more than -6.00 D, hyperopic astigmatism, unstable refraction for the last 12mo, residual corneal bed thickness <300 μm, dry eye, any type of corneal or media opacity, active ocular pathology, previous intraocular or corneal surgery, history of herpetic keratitis, immunodeficiency, systemic connective tissue diseases, insulin-dependent diabetes mellitus, clinical or subclinical corneal ectatic disease, history or suspect of glaucoma, iris irregularities, and pregnancy or breastfeeding. The study received the approval of the HVCC Ethics Committee. Patients were informed about the surgery and the clinical study, and provided informed consent to participate in it in accordance with the tenets of the Declaration of Helsinki.

Examination Protocol A preoperative ophthalmological examination was performed in all patients that included ocular and medical history, measurement of uncorrected distance visual acuity (UDVA) and corrected distance visual acuity (CDVA), manifest and cycloplegic refraction, slit-lamp examination of the anterior segment, Scheimpflug imaging-based corneal topography and pachymetry by means of the Pentacam HR system (Oculus. Optikgeräte, GmbH Wetzlar, Germany) in the WFG subgroups and Placido ring-based corneal topography with the WaveLight Topolizer system (Alcon) in the WFO subgroups, applanation tonometry (AT 900, Haag-Streit, Koeniz, Switzerland), contrast sensitivity (CS) testing (CVS-1000, Vistech), funduscopy and wavefront aberration measurement using the iDesign system (AMO Inc., Santa Ana, CA, USA) in both groups. With this aberrometer, the magnitude of the root mean square (RMS) for HOAs, primary coma and trefoil, and the magnitude of primary SA for a pupil aperture of 5 mm were calculated. Soft contact lenses and rigid gas permeable contact lenses were removed at least one week and three weeks, respectively, prior to this complete preoperative examination.

Postoperatively, clinical examinations were performed at 1d, 1, 3 and 6mo after surgery. These postoperative examinations included UDVA and CDVA measurement, manifest refraction, biomicroscopic examination, and topographic analysis. At the last postoperative visit, CS and aberrometric outcomes were also evaluated.

Surgery All surgeries were performed by the same surgeon (Khalifa MA) under topical anesthesia. Before surgery, all eyes were prepared by cleansing the periocular zone and two drops of topical anesthesia were instilled. Corneal flaps were created using the M2 microkeratome (Moria, Antony, France), with an intended flap thickness of 110 μm. In the WFG subgroups, the STAR S4IR excimer laser was used, with a WFG ablation calculated according to the iDesign aberrometric measurements. In the WFO subgroups, the Allegretto EX-500 excimer laser platform was used. An iris-based torsional registration was previously obtained in all cases and used to control torsional movements during surgery if necessary. Treatments were programmed with a 6-mm optical zone in both groups and assuming a refractive target of emmetropia in all cases. Standard topical postoperative treatment was administered to all patients consisting of a combination of dexamethasone and tobramycin four times a day during one week. Also, patients were instructed to use an artificial tear solution at least every two hours the day after the surgery and at least four times a day during one month. After this period, patients were instructed

Table 1 Preoperative clinical characteristics of the studied groups

Parameters	Low myopia			Moderate myopia		
	WFG	WFO	*P*	WFG	WFO	*P*
Sphere (D)			0.041			0.042
Mean (SD)	-1.90 (0.58)	-1.53 (0.74)		-4.21 (0.83)	-4.02 (0.89)	
Range	-3.00 to -0.63	-3.00 to -0.47		-5.88 to -2.88	-5.46 to -2.47	
Cylinder (D)			0.107			0.107
Mean (SD)	-1.20 (0.86)	-1.12 (1.32)		-1.31 (0.65)	-1.47 (1.26)	
Range	-3.25 to 0.00	-4.50 to 0.00		-2.75 to 0.00	-4.75 to 0.00	
SE (D)			0.023			0.098
Mean (SD)	-1.99 (0.60)	-2.15 (0.46)		-4.36 (0.84)	-4.67 (0.86)	
Range	-3.00 to -0.63	-3.00 to -1.38		-6.00 to -3.13	-6.00 to -3.38	
Decimal CDVA			0.041			0.104
Mean (SD)	1.07 (0.11)	0.99 (0.05)		1.01 (0.11)	1.00 (0.07)	
Range	0.80 to 1.20	0.80 to 1.20		0.90 to 1.20	0.80 to 1.20	

CDVA: Corrected distance visual acuity; SD: Standard deviation.

to use artificial tears when needed (foreign body sensation, dryness *etc.*).

Data Analysis The Alpins vector analysis method was used for the analysis of the astigmatic changes occurring after surgery[15-16]. The following vectors were determined and evaluated: targeted induced astigmatism (TIA) as the vector of intended change in cylinder for each treatment, surgically induced astigmatism (SIA) as the vector of the real change achieved and difference vector (DV) as the additional astigmatic change that would enable the initial surgery to achieve its intended target. Additionally, the following parameters derived from the relationship between these vectors were calculated and analyzed at the last postoperative visit. AE: the angle described by the vectors of the achieved correction (SIA) and the intended correction (TIA). Negative: achieved correction is clockwise to its intended axis. Positive: achieved correction is counterclockwise to its intended axis. Correction index (CI): the ratio of the SIA to the TIA-what the surgery actually induced versus what the surgery was meant to induce. The CI is preferably 1; it is greater than 1 if an overcorrection occurs and less than 1 if there is an undercorrection.

Concerning statistical analyses, all were performed with a commercially available software package (SPSS for Mac, Version 20.0; IBM Corporation, Armonk, NY, USA). Normality of data samples was evaluated by means of the Kolmogorov-Smirnov test. When parametric analysis was possible, the Student's *t*-test for unpaired data was used for comparisons between pairs of groups, whereas the Mann-Whitney test was applied to assess the significance of such differences when parametric analysis was not possible. For the analysis of differences between preoperative and postoperative visits in each group, the Student's *t*-test for paired data or the Wilcoxon ranked sum test were used depending if the samples were normally distributed or not, respectively. For all statistical tests, a *P*-value of less than 0.05 was considered as statistically significant. Finally, the efficacy index was calculated as the ratio of the postoperative UDVA to the preoperative CDVA, and the safety index was calculated as the ratio of the postoperative CDVA to the preoperative CDVA[17].

RESULTS

Table 1 summarizes the clinical characteristics of the studied groups.

Low Myopia Group Outcomes Significantly better decimal preoperative CDVA (WFG 1.07±0.11 *vs* WFO 0.99±0.05, *P*=0.041) and postoperative UDVA (WFG 1.07±0.13 *vs* WFO 0.95±0.14, *P*=0.011) was found in the WFG subgroup compared to WFO. A significantly better efficacy index was found in the WFG subgroup (WFG 1.00±0.10 *vs* WFO 0.96±0.11, *P*=0.041). A total of 41 (91%) and 47 eyes (87%) achieved a postoperative UDVA of 20/20 or better in the WFG and WFO subgroups, respectively (Figure 1). More patients achieved postoperative UDVA of 20/16 in the WFG subgroup compared to the WFO (44.4% *vs* 13.0%, *P*=0.001) (Figure 1). No differences in postoperative decimal CDVA (WFG 1.12±0.11 *vs* WFO 1.03±0.10, *P*=0.107) and safety index (WFG 1.05±0.11 *vs* WFO 1.03±0.12, *P*=0.275) were found among subgroups. Gains of lines of CDVA were observed in 15 (33.3%) and 18 eyes (33.3%) in the WFG and WFO subgroups, respectively (Figure 2). Losses of lines of CDVA were only observed in the WFO subgroup (1 eye, 1.9%) (Figure 2).

Manifest SE changed significantly from a mean preoperative value of -1.99±0.60 D to a mean postoperative value of -0.14±0.18 D (*P*<0.001) in the WFG subgroup and from -2.15±0.46 D to -0.49±0.39 D (*P*<0.001) in the WFO subgroup (Figure 3). No significant differences were observed between the SE achieved at 1 and 6mo postoperatively in any subgroup (WFG, *P*=0.322; WFO, *P*=0.582). No significant differences

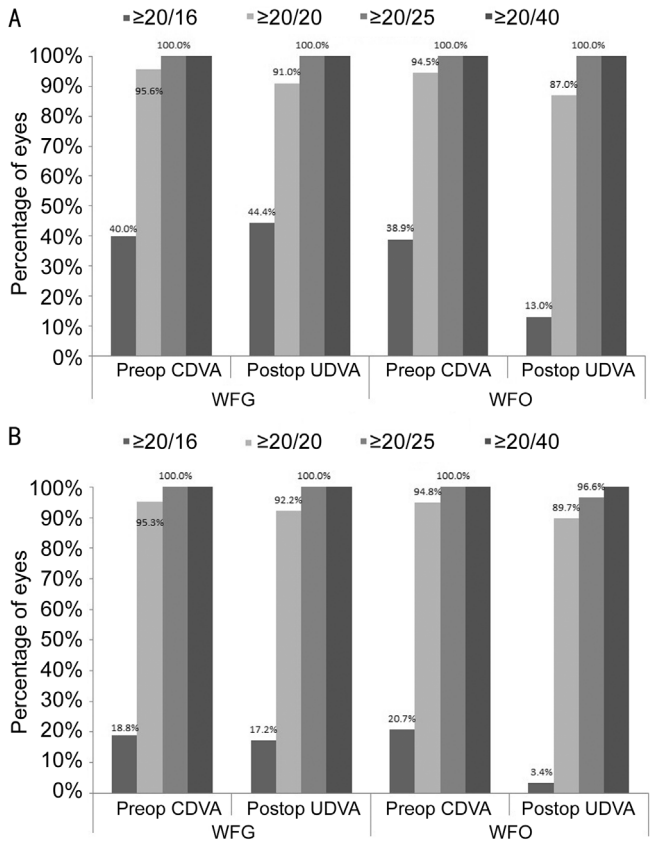

Figure 1 Distribution of preoperative CDVA and postoperative UDVA at 6mo after surgery in the WFG and WFO subgroups A: Low myopia group; B: Moderate myopia group.

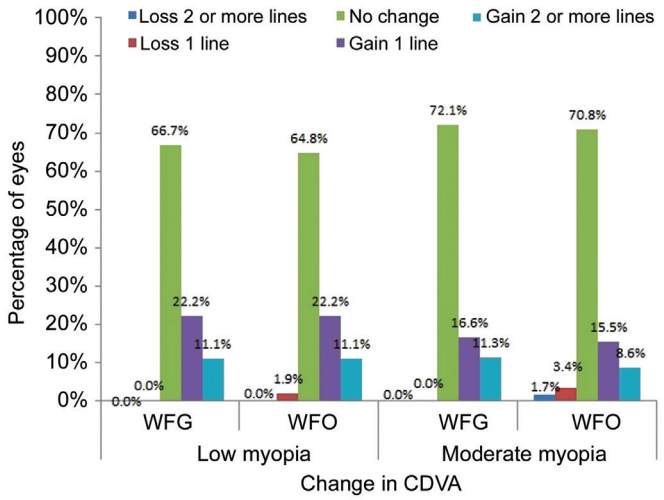

Figure 2 Change in CDVA during the follow-up in the WFG and WFO subgroups of the low and moderate myopia groups.

among groups were found in preoperative SE (P=0.098), but a higher postoperative value was present in the WFO subgroup compared to WFG (P=0.002). More patients in the WFG subgroup achieved a postoperative SE within ±0.25 D (WFG 84.4% *vs* WFO 66.8%, P=0.015) (Figure 4). Regarding manifest cylinder, it was reduced significantly with surgery in both subgroups (WFG: from -1.20±0.86 D preoperatively to -0.06±0.16 D at 6mo postoperatively, P=0.001; WFO: from -1.12±1.32 D preoperatively to -0.20±0.34 D at 6mo postoperatively, P=0.001). Significant differences between sub-

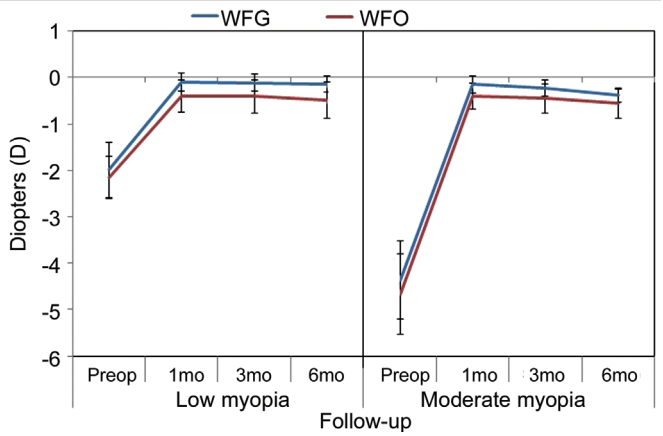

Figure 3 Change in the SE during the follow-up in the WFG and WFO subgroups of the low and moderate myopia groups.

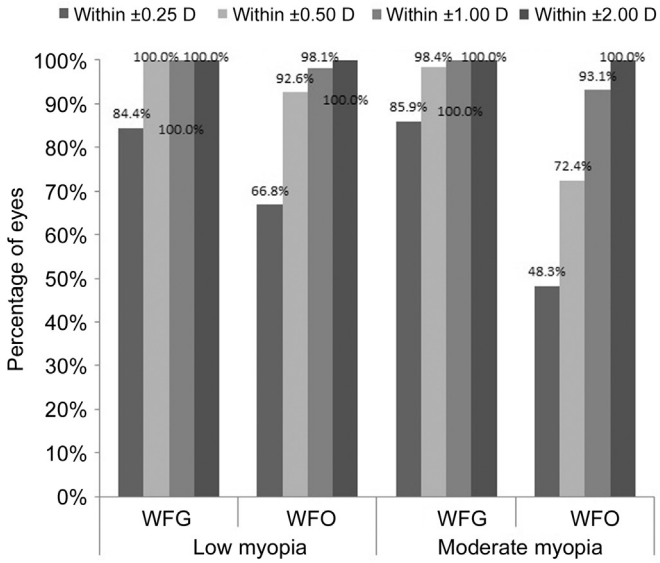

Figure 4 Distribution of the 6-month postoperative SE in the WFG and WFO subgroups of the low and moderate myopia groups.

groups were found in the magnitude of cylinder postoperatively (P=0.001) that were not present preoperatively (P=0.107). More patients had a 6-month postoperative cylinder of 0.25 D or below in the WFG subgroup compared to the WFO subgroup, but the difference was not statistically significant (WFG 88.9% *vs* WFO 74.1%, P=0.235) (Figure 5).

No significant changes in CS for any spatial frequency evaluated were found at 6mo postoperatively (P≥0.107). The change induced with surgery in primary coma (P=0.006) and SA (P=0.005) was significantly lower in the WFG subgroup compared to the WFO subgroup (Figure 6).

Moderate Myopia Group Outcomes No statistically significant differences among WFG and WFO subgroups were found in decimal preoperative CDVA (WFG 1.01±0.11 *vs* WFO 1.00±0.07, P=0.104). In contrast, significantly better postoperative UDVA (WFG 1.01±0.11 *vs* WFO 0.93±0.11, P=0.017) and better efficacy index (WFG 1.00±0.10 *vs* WFO 0.93±0.11, P=0.027) was found in the WFG subgroup compared to WFO. A total of 59 (92.2%) and 52 eyes (89.7%) achieved a postoperative UDVA of 20/20 or better in the

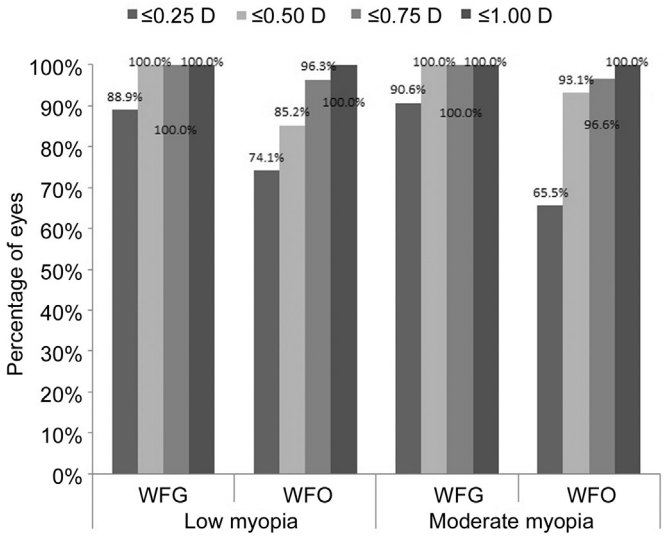

Figure 5 Distribution of the 6-month postoperative cylinder in the WFG and WFO subgroups of the low and moderate myopia groups.

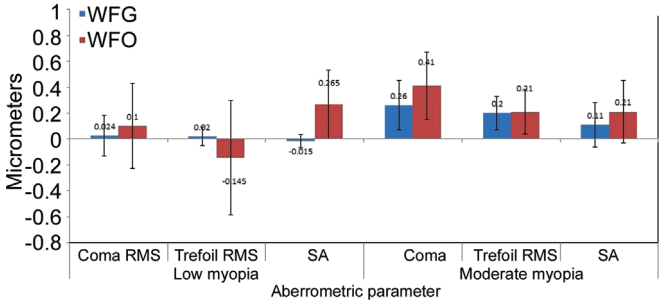

Figure 6 Distribution of the postoperative change in HOAs in the WFG and WFO subgroups of the low and moderate myopia groups.

WFG and WFO subgroups, respectively (Figure 1). More patients achieved a postoperative UDVA of 20/16 in the WFG subgroup compared to the WFO (17.2% *vs* 3.4%, *P*=0.001) (Figure 1). No significant differences among groups were found in postoperative decimal CDVA (WFG 1.08±0.12 *vs* WFO 1.01±0.08, *P*=0.106) and safety index (WFG 1.07±0.12 *vs* WFO 1.01±0.10, *P*=0.081). Gains of lines of CDVA were observed in 18 (27.9%) and 14 eyes (14.1%) in the WFG and WFO subgroups, respectively. Losses of lines of CDVA were only observed in the WFO subgroup (3 eyes, 5.1%).

Manifest SE changed significantly from a mean preoperative value of -4.36±0.84 D to a mean postoperative value of -0.38±0.16 D (*P*<0.001) in the WFG subgroup and from -4.67±0.86 D to -0.56±0.31 D (*P*<0.001) in the WFO subgroup (Figure 3). No significant differences were observed between the SE achieved at 1 and 6mo postoperatively in any subgroup (WFG, *P*=0.06; WFO, *P*=0.107). Lower SE was present preoperatively (*P*=0.023) and postoperatively (*P*=0.001) in the WFG subgroup compared to the WFO subgroup. More patients in the WFG subgroup achieved a postoperative SE within ±0.25 D (WFG 85.9% *vs* WFO 48.3%, *P*=0.001) (Figure 4). Regarding manifest cylinder, it was reduced significantly with surgery in both subgroups (WFG: from -1.31±0.65 D preoperatively to -0.09±0.16 D at 6mo postoperatively, *P*=0.001; WFO: from -1.47±1.26 D preoperatively to -0.25±0.30 D at 6mo postoperatively, *P*=0.001). The magnitude of cylinder differed significantly among subgroups in the last postoperative visit (*P*=0.003), but not preoperatively (*P*=0.107). More patients had a 6-month postoperative cylinder of 0.25 D or below in the WFG subgroup compared to the WFO subgroup (WFG 90.6% *vs* WFO 65.5%, *P*=0.002) (Figure 5).

Regarding CS, only a significant improvement was found in the WFG subgroup for the value obtained for the spatial frequency of 18 cycles/degree (*P*=0.028). The change induced with surgery in trefoil (*P*=0.001) and SAs (*P*=0.001) was significantly lower in the WFG subgroup compared to the WFO subgroup (Figure 6).

Vector Analysis of Astigmatic Changes Table 2 summarizes the parameters derived from the vector analysis of ocular astigmatic changes at the end of the follow-up in the WFG and WFO subgroups of the low and moderate myopia groups. In the low myopia group, a significantly larger magnitude of the DV was found in the WFO group compared to the WFG subgroup (*P*<0.001). In the moderate myopia group, a significantly larger magnitude of DV (*P*<0.001), ME (*P*=0.008), and AE (*P*<0.001) was found in the WFO subgroup compared to the WFG subgroup. Likewise, in this same group, a significantly higher CI was found in the WFG subgroup (*P*=0.001).

DISCUSSION

In the last years, advances in excimer laser keratorefractive procedures have been focused on improvements in ablation profile algorithms, flying spot profiles, and eye tracking systems[18-19]. The introduction of WFO and WFG ablation profiles has been an important step forward a maximal level of optimization of visual outcomes after laser refractive surgery[19]. Recently, new technical advances have led to a further improvement of WFG treatments. The development of high resolution aberration sensors, avoiding some of the limitations of previous aberrometers, and the development of the iris registration technology, allowing the compensation for torsional movements during surgery, are two of the main latest advances improving the results of WFG laser surgery[5]. According to this technological implementation, it is expected that WFG treatments provide better clinical outcomes than WFO procedures. There are some previous comparative studies evaluating the outcomes of WFG and WFO treatments[2,10,14,20-22]. Some of these studies found some clinical benefits of WFG over WFO treatments whereas others did not[2,10,14,20-22]. The current study was aimed at comparing the outcomes of WFG LASIK treatments based on measurements obtained with a high resolution aberrometer and WFO with cyclotorsional registration in low to moderate myopic eyes with astigmatism, which are the most frequent cases that commonly undergo laser refractive surgery. To our knowledge, this is the first study evaluating and comparing the

Table 2 The parameters derived from the vector analysis of ocular astigmatic changes at the end of the follow-up in the analyzed sample (Alpins method)

Parameters	Low myopia			Moderate myopia		
	WFG	WFO	*P*	WFG	WFO	*P*
TIA (D)			0.166			0.822
Mean (SD)	1.36 (0.85)	1.12 (1.35)		1.39 (0.62)	1.64 (1.26)	
Median (range)	1.50 (0.25 to 3.25)	0.51 (0.05 to 4.57)		1.50 (0.25 to 2.75)	1.37 (0.44 to 4.91)	
SIA (D)			0.053			0.699
Mean (SD)	1.32 (0.81)	0.95 (1.07)		1.32 (0.53)	1.41 (1.05)	
Median (range)	1.26 (0.25 to 3.25)	0.46 (0.03 to 3.68)		1.25 (0.25 to 2.50)	1.16 (0.30 to 4.15)	
DV (D)			<0.001			<0.001
Mean (SD)	0.08 (0.18)	0.47 (0.41)		0.10 (0.17)	0.53 (0.32)	
Median (range)	0.00 (0.00 to 0.50)	0.27 (0.08 to 1.69)		0.00 (0.00 to 0.50)	0.52 (0.14 to 1.52)	
ME			0.902			0.008
Mean (SD)	0.05 (0.16)	0.18 (0.45)		0.08 (0.16)	0.23 (0.40)	
Median (range)	0.00 (-0.32 to 0.50)	0.06 (-0.39 to 1.68)		0.00 (-0.24 to 0.50)	0.21 (-0.59 to 1.50)	
CI			0.617			0.001
Mean (SD)	0.99 (0.13)	1.30 (1.22)		0.97 (0.10)	0.88 (0.26)	
Median (range)	1.00 (0.67 to 1.64)	0.77 (0.36 to 6.56)		1.00 (0.74 to 1.48)	0.81 (0.52 to 1.49)	
AE (º)			0.541			<0.001
Mean (SD)	0.45 (3.18)	-2.81 (20.95)		-0.04 (0.87)	-1.15 (12.36)	
Median (range)	0.00 (-4.71 to 17.50)	0.00 (-59.04 to 58.35)		0.00 (-3.92 to 3.80)	-0.56 (-27.88 to 44.97)	

TIA: Targeted intended astigmatism; SIA: Surgically induced astigmatism; DV: Difference vector; ME: Magnitude of error; AE: Angle of error; CI: Correction index; SD: Standard deviation. Ocular astigmatic changes in the analyzed sample.

efficacy of the astigmatic correction achieved with both types of laser ablation profile using vector analysis.

In our study, better postoperative UDVA and efficacy index were found in low and moderate myopic eyes with WFG treatments compared to WFO. This was related to a relatively more limited predictability of the refractive correction achieved with WFO profiles. Indeed, postoperative SE and cylinder was significantly higher with WFO treatments compared to WFG for both low (-0.14±0.18 D *vs* -0.49±0.39 D, *P*=0.002) and moderate (-0.38±0.16 D *vs* -0.56±0.31 D, *P*=0.001) myopic eyes. Likewise, more patients with low (84.4% *vs* 66.8%, *P*=0.015) and moderate myopia (85.9% *vs* 48.3%, *P*=0.001) undergoing a WFG procedure achieved a postoperative SE within ±0.25 D. This is consistent with the results of other comparative studies of WFO and WFG LASIK using other excimer laser platforms. He *et al*[14] found in a comparative study of WFO (Alcon Allegretto Wave Eye-Q 400 Hz excimer laser) and WFG femtosecond-assisted myopic LASIK (AMO Visx CustomVue S4 IR excimer laser combined with the previous version of the aberrometer used in our that had 5 times less resolution) a more myopic postoperative SE in those eyes undergoing the WFO treatment (-0.13±0.46 D *vs* -0.41±0.38 D). Sales and Manche[21] compared the clinical outcomes of WFO and WFG femtosecond-assisted LASIK performed with the Alcon WaveLight Allegretto Eye-Q 400-Hz excimer laser platform. These authors[21] found that the frequency with which the WFG group attained a refractive error within ±0.25 D of emmetropia was higher with the WFG ablation profile than with the WFO ablation (67.6% *vs* 41.2%, *P*=0.03). Likewise, they confirmed that postoperative UDVA in the WFG group was better than in the WFO group by approximately 1 Early Treatment Diabetic Retinopathy Study line (-0.17±0.11 *vs* -0.13±0.12, *P*=0.05)[21]. Taneri *et al*[10] found using the Technolas Zyoptix excimer laser platform that 67% of eyes treated with LASIK using a WFG profile and 39% of eyes treated with a WFO profile achieved a 20/20 UDVA or better. All these previous outcomes and the results of our study suggest the presence of a relative limitation with WFO ablation profiles in the predictability of the refractive correction that has a significant impact on the visual outcome achieved.

In our series, the less predictable correction of the cylinder with the WFO ablation compared to WFG seems to be the main factor contributing to the more limited predictability of SE correction with this type of ablation in both low and moderate myopic eyes. Indeed, a significantly higher magnitude of postoperative cylinder was found in eyes treated with WFO ablation profiles compared to those treated with WFG profiles (low myopia: -0.06±0.16 *vs* -0.20±0.34 D, *P*=0.001; moderate myopia: -0.09±0.16 *vs* -0.25±0.30 D, *P*=0.003). Furthermore, in our study, the percentage of eyes with a postoperative cylinder of 0.25 D or below was higher in WFG subgroups compared to WFO subgroups. This difference only reached statistical significance in the group of eyes with moderate myopia (low myopia: 88.9% *vs* 74.1%, *P*=0.235; moderate myopia: 90.6% *vs* 65.5%, *P*=0.002).

As the astigmatism is a vector parameter, not only changes in its magnitude must be analyzed, but also changes in its axis. For this reason, a vector analysis was performed considering both astigmatic magnitude and axis changes. According to this analysis, the difference between the intended and SIA, which is the DV, is related to the more limited predictability of cylinder correction with WFO ablation patterns. Higher levels of DV were found in WFO subgroups compared to WFG subgroups for both low and moderate myopia groups. This finding suggests that the use of wavefront aberration data allows a more precise planning of the optimal cylinder magnitude and axis to correct with the laser ablation. The high resolution aberrometer used for planning WFG treatments has been shown to provide reliable measurements of astigmatism that completely agree with that corresponding to manifest refraction[23]. Besides the difference in DV among WFG and WFO subgroups, ME and AE were also significantly higher in the WFO subgroup of the moderate myopia group. This is consistent with the results of Toy *et al*[2] who found that the AE was 80% less in eyes treated with WFG profiles using the Alcon WaveLight Allegretto Eye-Q 400-Hz excimer laser platform compared to those treated with WFO profiles (1.92°±0.67º *vs* 9.66°±3.7º, *P*=0.04). This finding suggests a potential level of misalignment of the cylinder correction leading to some level of astigmatic undercorrection when the treatment is applied using a WFO profile instead of a WFG laser ablation. It should be considered that the potential interaction among HOAs that may affect or interfere with an effective correction of astigmatism is taken into account when a WFG ablation profile is calculated[24]. This contributes to the more optimized outcome in terms of astigmatic correction that is observed after WFG LASIK compared to WFO LASIK.

Besides visual and refractive outcomes, ocular aberrometric changes were evaluated as well in our series. Higher post-operative levels of HOAs were found in WFG subgroups compared to WFO subgroups in both low and moderate myopia groups, which is consistent with the results of previous studies comparing WFO and WFG LASIK[10,21-22,25-26]. Specifically, significantly lower induction of SA was found after WFG LASIK in both low and moderate myopia groups as well as lower induction of trefoil, but only in eyes with moderate myopia. Similarly, more induction of SA with WFO profiles was found by Taneri *et al*[10] in a comparative study of WFO and WFG LASIK using the Technolas Zyoptix platform. Likewise, Sales and Manche[21] found in another comparative study that myopic eyes undergoing WFG LASIK had less postoperative trefoil compared with those undergoing WFO LASIK. In contrast, He *et al*[14] did not find significant differences in the postoperative levels of residual astigmatism (*P*=0.798) or HOAs (*P*=0.869) after WFO and WFG femtosecond-assisted LASIK. These discrepancies among studies may be attributed to several factors including differences in study populations, clinical procedures followed and excimer laser platforms used. For this reason, a significant variability in terms of CS outcomes can be found in different previous studies comparing the visual performance after WFO and WFG LASIK[2,10,14,20-22]. In our study, no significant changes in CS were found in low myopic eyes with WFG or WFO treatments, but a significant improvement in CS was observed in the WFG subgroup of the moderate myopia group for the spatial frequency of 18 cycles/degree.

Finally, no significant differences in terms of safety were found between WFO and WFG subgroups in both low and moderate myopia groups of our sample, with no significant differences in postoperative CDVA and safety index. Losses of lines of CDVA were only reported in a minimal number of patients operated on with WFO ablation profiles. Therefore, the difference in the control of HOAs with WFG and WFO ablation profiles detected in the two groups of our sample did not have a significant impact on the maximum level of visual acuity achievable by the patient. This may be due to the low level of aberrometric induction with both types of ablation profiles. Possibly, in eyes with high myopia, this impact is more significant as the difference in the level of induction of HOAs with WFG and WFO profiles is considerably higher. Al-Zeraid and Osuagwu[27] found higher level of induction of HOAs in eyes with high myopic astigmatism undergoing WFG LASIK compared to those with moderate myopic astigmatism. Other authors comparing WFG and WFO LASIK have reported significant differences in CDVA between ablation profiles, such as He *et al*[14].

In conclusion, WFG LASIK provides a more efficacious correction of astigmatism in eyes with low to moderate myopic astigmatism than WFO LASIK, with better control of HOAs leading to a more optimized visual outcome. The less induction of HOAs and more predictability of cylinder correction may be attributed to variable factors such as better axial and torsional registration with centroid shift, high resolution detection of the aberrations with more detailed ablation profile, and more delivery of energy to the midperiphery of the cornea. Future comparative studies in eyes with high myopic astigmatism should be conducted in order to confirm if the benefit of WFG over WFO treatments is still higher.

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