Comparisons of Modulation Transform Function in 2 Monofocal Spherical Hydrophobic and Hydrophilic Intra Ocular Lenses

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Abstract- To compare Modulation Transform Function (MTF) between standard monofocal spherical hydrophobic acrylic Alcon SA60AT (Bausch and Lomb) and hydrophilic acrylic Rayner Superflex (620H) (Rayner) intra-ocular lenses (IOLs). This cross-sectional study was conducted on 68 patients who underwent cataract surgery. The hydrophobic Alcon SA60AT IOL was implanted in 39, and the hydrophilic Rayner Superflex (620H) was implanted in 29 eyes. The OPD Scan III (Nidek) was used to assess MTF in normal pupils under mesopic light conditions 1 and 3 months after the surgery. *t*-test showed no significant difference in mean MTF between the two IOLs in the 2 follow-ups (P=0.788). The results of repeated measure ANOVA for each type of IOL indicated that MTF increased significantly in the hydrophilic group versus the hydrophobic group in the 3rd month (P=0.033). Moreover, the results of repeated measure ANOVA showed that MTF was affected by the type of IOL and refractive error in the 3rd month (P=0.029, P=0.025). It seems that the material of IOL and post-surgical residual refractive error can affect the visual acuity of pseudophakic patients. Although the hydrophilic IOL provided a better MTF three months after the surgery, studies with longer follow-ups are required to confirm the results.

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Keywords: Intraocular lens; Spherical; Hydrophobic; Hydrophilic; Modulation transform function

Introduction

Visual quality is an important indicator of patient satisfaction after cataract surgery. Although achieving an uncorrected visual acuity (UCVA) of 20/20 is a criterion for successful cataract surgery outcome, it alone cannot be used to indicate patient satisfaction since some patients experience problems like glare, halo vision, decreased night vision, etc., despite having optimal visual acuity (VA), which result from some optical phenomena in the visual system or the intraocular lens (IOL) (1,2).

A review of the literature shows that the reason for dissatisfaction in pseudophakic individuals with no ocular pathology and good VA after cataract surgery is not a residual refractive error but some optical disorders resulting from IOL implantation (3).

Modulated Transform Function (MTF) is a criterion for the quantitative assessment of optical quality (4). A conventional definition of MTF is based on the spatial frequency and visual system performance in different contrasts (5). In other words, MTF is defined as the image contrast amplitude divided by the object contrast amplitude (5). MTF indicates a worsening of the image contrast in comparison with the object. The vaster the MTF graph is, there are more frequencies in the image,

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and therefore the image quality is better (6). A frequency of c/mm is almost equal to 30 cpd and represents a VA of 20/20 (7). Optical errors can affect image quality, contrast sensitivity, and MTF. Optical errors resulting from the IOL, like tilt and decentration, may change the MTF shape (8).

Moreover, the spatial frequencies that pass through the IOL may differ according to the lens material and shape (9). Therefore, it is important to select an appropriate IOL to improve VA. Aspheric and multifocal lenses are a new generation of lenses used in cataract surgery. Although aspheric intraocular lenses can markedly decrease spherical aberrations, they do not enhance the VA at the same level, mainly due to pupil diameter effects and corneal aberrations (10). Moreover, multifocal IOLs that have been designed for near vision have shortcomings like decreased contrast sensitivity, glare, halo vision, and pupil size dependence (11,12) Kawamorita and Uozato (13) reported that far MTF was lower in multifocal versus monofocal IOLs, and the difference increased with decreasing the spatial frequency. Moreover, they stated that far contrast sensitivity and far VA in each pupil size and spatial frequency were lower in eyes implanted with multifocal IOLs in comparison with their monofocal counterparts, while visual function in near vision was higher with multifocal IOLs. The decrease in MTF in multifocal IOLs may be due to the suppressive effect of in-focus and out-of-focus images produced by focusing components of far and near vision (13).

Although some studies have compared the image quality between monofocal and multifocal IOLs or spherical and aspherical lenses, no study has compared the image quality between hydrophobic and hydrophilic spherical monofocal IOLs, which was the aim of this study.

Materials and Methods

This cross-sectional study was conducted on 68 patients aged 40-68 years who underwent cataract surgery (phacoemulsification) by an experienced surgeon. Thirty-nine and 29 eyes were implanted with Alcon SA60AT hydrophobic and Rayner Superflex (620H) hydrophilic IOLs, respectively. Table 1 presents the characteristics of the lenses. The surgery was performed using the horizontal phaco chop method with a 2.8mm incision, 360° overlapping 5 mm capsulorhexis, and the lens was implanted in the capsular bag. Patients with diabetes, hypertension, cornea, macular or optic nerve pathology, peripheral opacities, glaucoma, uveitis, history of ocular surgery except for cataracts, and pupil irregularities were excluded from the study. VA measurement, aberrometry, slit lamp biomicroscopy, and fundoscopy were performed on each patient one and three months after cataract surgery.

Table 1. Characteristics of the intra-ocular lenses.

IOl characteristic	Alcon SA60AT	Rayner Superflex
Type	1-piece	1-piece
Overall length (mm)	13.0	12.5
Overall Diameter (mm)	6.0	6.25
Optic Material	Hydrophobic Acrylic(Ultraviolet-absorbing Acrylate/Methacrylate Copolymer)	Hydrophilic Acrylic(2- Hydroxy Ethyl Methacrylate/Hydrophobic Metyl Methacrylate)
Haptics Edge	Planar Haptics	Squared edge
Refractive Index	1.55	1.46
Optic design	Anterior Asymmetric Biconvex	Equi-Convex
Estimated A-constant	118.4	118

IOL: intra ocular lens

Visual acuity measurement (VA)

First, we measured uncorrected monocular distance visual acuity (UCVA). After objective refraction, best-corrected distance visual acuity (BCVA) was measured subjectively. If the distance BCVA reached 20/20, other examinations were performed. The patient was excluded if the post-surgical residual sphere and cylinder were greater than ±1D.

MTF assessment

The OPD scanner is a scanning slit refractometer that uses the double pass technique and retinoscopy simultaneously with placid disk topography. The OPD scanner uses dynamic retinoscopy to measure aberrations using the data of 1440 points. This device assesses MTF based on wavefront aberration. Aberrometry was performed using the OPD scan III

device on normal pupils without mydriatics or cycloplegics under scotopic conditions. The patients first underwent wavefront and then monocular topography for the measurement of corneal aberrations. After the tests were finished, the device analyzed the data and provided the MTF graph. This graph shows the necessary contrast required by patients to visually detect the shapes of the visual acuity chart as a percentage on the y-axis and visual acuity on the x-axis. Spatial frequency (cpd) is also shown along the x-axis. The graph also presents the emmetropic eye curve. In this device, the ratio between the area between the horizontal and vertical axis to the normal eye curve is reported as a percentage; the closer the value is to 100%, the closer the patient's curve to the normal eye. This device can report MTF in pupil diameters of 4, 5, and 6 mm. We registered the values for 6-mm pupils.

Data analysis

We used SPSS version 20 for descriptive and analytical analysis. For descriptive analysis, we reported the mean MTF along with the standard deviation for both IOLs. We used repeated measures analysis of variance considering the objective of the study for analytical analysis. T-test was used to compare the results of both groups at each follow-up.

Ethical issues

The Ethics Committee of "…" the University of Medical Sciences approved the study protocol. The study adhered to the tenets of the Helsinki Declaration. All participants signed written informed consent. (Ethics Code: 4/652D/26/P).

Results

We evaluated 68 pseudophakic normal eyes in this study. Thirty-nine and 29 eyes were implanted with Alcon SA60AT hydrophobic and Rayner Superflex (620H) hydrophilic IOLs, respectively. The mean age of the participants was 59.6±6.7 years (range: 40-68 years), and 26 of them (37.7%) were male. Two participants (both in the hydrophobic group) did not return for the first follow-up, and 9 participants (4 in the hydrophobic and 5 in the hydrophilic group) were absent in the second follow-up.

Refraction results

Table 2 shows the mean sphere, cylinder, and SE one and three months after the surgery. According to the results of the *t*-test, spherical refractive errors showed a significant hyperopic shift in the hydrophilic group in both follow-ups (*P*=0.010 and *P*=0.002, respectively), while no significant difference in the mean cylinder was observed between the two groups in the first (*P*=0.686) and second (*P*=0.225) follow-ups. According to repeated measures ANOVA, the trend of the sphere and cylinder changes was not significant between the two groups in the first and second follow-up (*P*=0.173 and *P*=0.305, respectively), although the hyperopic shift in the equivalence sphere was slightly higher in the hydrophilic group (*P*=0.071).

Table 2. Subjective refraction results in hydrophobic and hydrophilic Intraocular lenses groups in two follow-ups

	Hydrophobic IOL		Hydrophilic IOL		*P*
	Mean±SD	Range	Mean±SD	Range	
Sphere(f/u1)	0.02±0.49	-1.00 to 1.25 D	0.31±0.39	-0.50 to 1.00D	0.010
Cylinder(f/u3)	-0.52±0.29	-1.00 to 0.00 D	-0.48±0.41	-1.25 to 0.00D	0.686
Spherical equivalent (f/u1)	-0.22±0.48	-1.38 to 0.87 D	0.09±0.39	-0.75 to 0.87D	0.007
Sphere(f/u3)	0.08±0.48	-0.75 to 1.25	0.46±0.38	-0.25 to 1	0.002
Cylinder(f/u3)	-0.53±0.40	-1.25 to 0.25	-0.41±0.34	-1.00 to 0	0.225
Spherical equivalent f/u3)	-0.19±0.43	-1.12 to 0.75	0.26±0.40	-0.50 to 1	<0.001

P-value calculated by independent sample T-test, f/u: follow up, SD: Standard Deviation, IOL: intraocular lens

MTF results

Table 3 presents the mean MTF in the first and third months between the two groups. T-test showed no significant changes in MTF between the two groups in the first month (*P*=0.897), while the mean MTF was higher in the hydrophilic group in a borderline significant manner (*P*=0.059).

The results of the present study showed no significant trend in MTF in the two groups from the first to the third-month post operation (*P*=0.788). However, as Figure 1 shows, after the separation between the two lenses, repeated measures ANOVA revealed a significant difference between the two groups during the first and the third month; MTF decreased in the

hydrophobic and increased in the hydrophilic group significantly (*P*=0.033). The results of repeated measures ANOVA after adding the pupil diameter, refractive error, total corneal aberrations, total internal aberrations, and total aberrations in each follow-up as confounders showed that MTF was only affected by the IOL type and the refractive error 3 months after the surgery (*P*=0.029 and *P*=0.025, respectively).

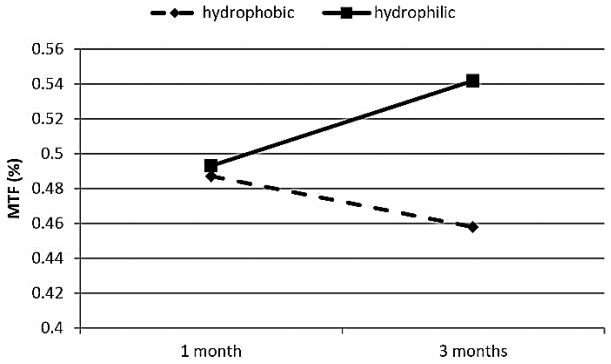

Figure 1. The trend of Modulation Transform Function changes from the first to the third month in hydrophobic and hydrophilic intra-ocular lens groups

Table 3. Modulation transform function values in hydrophobic and hydrophilic intraocular lenses groups in two follow-ups

	Hydrophobic IOL	Hydrophilic IOL	
	Mean±SD	**Mean±SD**	***P***
MTF 1	0.487±0.187	0.493±0.161	0.897
MTF 3	0.458±0.154	0.542±0.182	0.059

MTF 1: MTF at 1 months post-op, MTF 3: MTF at 3 months post-op
P calculated by independent sample T-test, IOL: intraocular lens

Discussion

We found no significant differences in MTF between the two groups in the two follow-ups; however, in the third month, pseudophakic patients with hydrophilic lenses showed a marginally better MTF as compared with the hydrophobic group (*P*=0.059).

Mayank *et al*., (4) reported that hydrophilic IOLs offered a lower image quality in comparison with their hydrophobic counterparts and attributed this finding to the increased opacity of hydrophilic IOLs due to more water capacity. Since no patient had posterior capsular opacification in our study, this hypothesis was rejected in our study conducted shortly after cataract surgery. Although Tognetto *et al*., (9) reported that most spatial frequencies passed through acrylic IOLs with a higher refractive index and an unequal biconvex design and mentioned decreased aberrations in this design as the reason, Vilarrodona *et al*., (14), after evaluating optical aberrations in 48 pseudophakic eyes with 4 different IOLs (in terms of design and material), stated aberrations increased significantly more in pseudophakic eyes implanted with two types of acrylic IOLs when compared with pseudophakic eyes implanted with PMMA or silicone IOLs. They reported that IOLS with higher refractive indexes induced higher aberrations and therefore presented lower-quality images. These discrepancies in the results of different studies indicate that the retinal image quality is not merely affected by the material and design of the lens, and the role of other factors should be evaluated.

According to the ISO standard, the MTF should be greater than 0.43 at the frequency of 100 cycles/mm with a diameter of 3 mm for all IOLs. If MTF is lower due to the lens design, it should be higher than 70% of the theoretical value for the design at the frequency of 100 cycles/mm, and it should be greater than 0.28 at 100 cycles/mm in all lens designs. In our study, as shown in Table 3, the mean MTF was more than 0.43 at the frequency of 100 cycles/mm in both groups in both follow-ups, indicating that both lenses can produce acceptable retinal images in pseudophakic individuals.

Another finding of our study was the hyperopic shift in pseudophakic individuals implanted with hydrophilic IOLs, which can rather explain the higher MTF in the hydrophilic group. As we already know, hyperopic patients have better visual performance after cataract surgery when compared with myopic and emmetropic

patients (15). This finding may indicate that hyperopia can have a compensatory role for spherical aberration resulting from tilt or decentration of the IOL (15). Moreover, it has been reported that old pseudophakic and phakic individuals tolerate small amounts of defocus better than young phakic patients, which is an advantage in pseudophakic eyes with aberrations because it enhances the quality of the retinal image (16). Therefore, the hyperopic shift observed in the hydrophilic in the third month, when aberrations did not show a significant difference between the two groups, maybe a suitable explanation for the higher MTF in this group.

It seems that in clinical cases, MTF is very useful for presenting an appropriate model of visual quality after procedures that change the optical conditions of the eye.[4] Our study also demonstrated the relative superiority of hydrophilic IOLs after 3 months, although no difference was initially observed in MTF between the two groups. This finding highlights the importance of long-term follow-up of pseudophakic individuals. Moreover, this clinical point should be kept in mind that patients should be given information on the trend of visual quality changes and visual quantity stabilization before cataract surgery. The information can be well explained based on MTF changes.

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