# Retinal image quality after microincision intraocular lens implantation

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**PURPOSE:** To evaluate the modulation-transfer function (MTF) in eyes implanted with a conventional intraocular lens (IOL) and 2 IOLs designed for microincision cataract surgery (MICS).

**SETTING:** Research, Development, and Innovation Department, Instituto Oftalmológico de Alicante, Alicante, Spain.

**METHODS:** This prospective nonrandomized consecutive series comprised 30 eyes implanted with 1 of the following IOLs: conventional acrylic foldable (AcrySof MA60BM, Alcon Laboratories) or the UltraChoice 1.0 ThinOptX (ThinOptX Inc.) or the Acri.Smart 48S (Acri.Tech) MICS IOL. The 0.5 MTF and 0.1 MTF following MICS were calculated 3 months after implantation with the Optical Quality Analysis System (OQAS) for a 5 mm pupil. The differences were statistically analyzed with the Mann-Whitney *U* test.

**RESULTS:** The values of 0.5 MTF for AcrySof, UltraChoice, ThinOptX, and Acri.Smart IOLs were, respectively, 2.647 cycles per degree (cpd) $\pm$ 0.833 (SD), 2.601 $\pm$ 0.986 cpd, and 3.453 $\pm$ 0.778 cpd. The mean 0.1 MTF values for the same IOLs were 8.720 $\pm$ 3.074 cpd, 8.814 $\pm$ 4.380 cpd, and 11.418 $\pm$ 2.574 cpd, respectively. Statistical analysis did not show significant differences in 0.5 MTF and 0.1 MTF between the conventional IOL and MICS IOLs.

**CONCLUSIONS:** Microincision cataract surgery IOLs showed excellent MTF performance when implanted after cataract surgery, equal to that of conventional IOLs. An in vivo MTF study may be an excellent option to evaluate IOL performance in the eye.



Today, cataract extraction is not only considered a therapeutic procedure for cataract itself but also a refractive surgery procedure. The accuracy of the visual and refractive results is continuously increasing due to the high level of precision and reliability that the technique has reached. This implies precise intraocular lens (IOL) power calculation and a reduction of the incision size to minimize the surgically induced astigmatism (SIA). Microincision cataract surgery (MICS) is a procedure performed using incisions of 1.5 mm or smaller, the aim being to decrease surgical aggressiveness and to eliminate SIA.[1] The IOLs for MICS must be rollable to be implanted or injected under high pressure with the aid of a hydraulic injector. Such a maneuver might affect the optical performance of the lens once implanted in the eye.

The development of MICS has lead to the development of a new generation of IOLs able to be implanted through an incision of sub-2 mm size. When an IOL is implanted, the quality of the retinal image could be degraded because of a defocus due to induced astigmatism, and further, because of a diffraction phenomenon at the pupil margin, light scattering, and corneal and intraocular lens aberrations. In vitro, monofocal IOLs have a better optical quality than the healthy crystalline lens.[2–4] However, the final optical quality in pseudophakic patients was not better than that

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in healthy subjects.[5,6] Studies have shown that 3rd-order spherical aberrations and coma were significantly larger for the cornea than for the whole eye, which suggests that the crystalline lens compensates for the corneal aberrations.[2] Corneal and crystalline lens aberrations tend to cancel each other (an example of coupling of 2 optical systems). This apparent disagreement between optical quality of IOLs in vivo and in vitro can be explained by considering the aberration coupling of the optical system.

The purpose of this study was to evaluate in vivo the optical quality of the eye with different types of IOLs for MICS and compare it with the quality of a conventional IOL.

## PATIENTS AND METHODS

Thirty eyes of 18 patients had MICS and implantation of 1 of 3 types of posterior chamber IOLs. Ten eyes received a conventional, foldable, small-incision IOL (AcrySof MA60BM, Alcon Laboratories), and 10 eyes each received 1 of 2 MICS IOLs (UltraChoice 1.0, ThinOptX, or Acri.Smart 48S, Acri.Tec). The series was prospective, nonrandomized, and consecutive. All surgeries were consecutively performed at the Instituto Oftalmológico de Alicante, Spain, by 2 surgeons (J.L.A., J.L.R.P.) and followed by an independent observer.

The tenets of the Declaration of Helsinki were followed in the study. Following explanation of the nature of the procedure and possible consequences of the study, an informed consent form was signed by all patients.

Patient inclusion criteria were MICS followed by posterior chamber IOL implantation of conventional or MICS IOL, 3 months of follow-up, a best corrected distance visual acuity of 20/25 or better, a well-positioned IOL, no intraoperative or postoperative complications, and a normal eye, determined by slitlamp biomicroscopy and fundoscopy. Patients with opacification of the ocular media, corneal surface problems, or retinal disease were excluded.

In patients who had bilateral cataract extraction, the type of IOL implanted was the same in both eyes. The mean difference in IOL power between eyes was 0.64 diopter (D) $\pm$ 0.55 (SD).

The male patient to female patient ratio was 10:8. The mean age was 73.9 $\pm$ 6.7 years (range 61 to 83 years).

### Microincision Cataract Surgery

Surgery was performed with topical anesthesia in all cases. First, 2 microincisions (1.5 mm each) were created, 1 for the irrigation and the other for the aspiration channel. The primary incision (later used for the IOL implantation) was situated at the positive corneal meridian obtained by corneal topography. After the anterior chamber was filled with viscoelastic material, a capsulorhexis was performed. A capsulorhexis was performed using the Alio MICS capsulorhexis forceps (Katena). After hydrodissection, manual prechopping was performed using the Alio MICS pre-choppers followed by low ultrasound phacoemulsification. The residual cortex was eliminated and posterior capsule cleaning performed at the end. Before the IOL implantation, the capsular bag was filled with viscoelastic material. In patients in whom an AcrySof was implanted, the incision was enlarged to 3.2 mm. The UltraChoice and Acri.Smart IOLs were implanted with an injector through a 1.6 to 1.8 mm incision.

The viscoelastic material was aspirated using an irrigation/aspiration cannula through the same incisions. In all cases, the procedure was concluded with hydration of the 2 microincisions.

Postoperatively, dexamethasone 0.1%—tobramycin 0.3% (TobraDex) was instilled 3 times per day for 3 weeks.

### Intraocular Lenses

The UltraChoice 1.0 is a posterior chamber IOL of a hydrophilic acrylic material. The central thickness of the optic is from 350 μm to 450 μm; for a 20.00 D IOL, the central thickness is 450 μm. The lens has a meniscus-shape format. The posterior surface of the lens has a central clear portion (3 mm), which is surrounded by a series of concentric, planar, annular rings of increasing diameter. To be implanted in the capsular bag, the lens was warmed at 40°C for 5 minutes, then held with a forceps and rolled between the index and thumb in a rubbing motion. The lens was then inserted through the corneal wound using a toothless corneal forceps and implanted in the capsular bag.

The Acri.Smart 48S is a 1 piece, foldable acrylic IOL with hydrophobic surfaces and a water content of 25% in its fully hydrated state. It has an optic diameter of 5.5 mm, a spherical design, and an overall size of 11.0 mm. The haptic and optic have square truncated edges. The available powers range from plano to +32.0 D. The lens is made from AcriLyc material, a copolymer of hydroxyethylmethacrylate and ethoxymethacrylate with an ultraviolet absorber. The central thickness of a 23.00 D IOL is 700 μm.

To be implanted in the capsular bag, the Acri.Smart lens is placed, completely open, in its cartridge and which is with viscoelastic material. It is then pushed into the cartridge channel. Afterward, the cartridge wings are closed. The cartridge is inserted into the injector, and the plunger with its silicone stopper is introduced slowly into the aperture of the cartridge. Using slight pressure, the plunger is advanced and the lens is introduced into the capsular bag.

The AcrySof MA60BM is a foldable acrylic IOL with an optic diameter of 6.0 mm. The central thickness for a 20.00 D IOL is 820 μm and for a 23.00 D IOL is 880 μm.

### Optical Quality Evaluation

The optical quality was studied by the modulation transfer function (MTF) for monochromatic light. The MTF is the ratio of the image wave contrast to the object wave contrast.

The MTF was measured with the Optical Quality Analysis System (OQAS, Visiometrics S.L.), a new instrument based on the double-pass technique that was developed to perform an objective evaluation of the optical quality of vision. The double-pass technique is based on recording images of a point source after reflection on the retina and double-pass through the ocular media.[7] The design of OQAS is based on the asymmetric scheme of a double-pass technique layout incorporating new features adapted for routine measurements in clinical practice (J. Pujol, et al., "New Double-Pass Instrument for Clinical Evaluation of the Optical Quality After Refractive Surgery," paper presented at the annual meeting of the American Academy of Ophthalmology, Orlando, Florida, USA, October 2002). Thus, with this configuration the ocular point spread function (PSF) can be obtained. To do measurements with a determined value of pupil diameter, the instrument incorporates a circular diameter diaphragm. The diaphragm is conjugated with the eye pupil plane and therefore acts as an effective entrance pupil when the natural pupil of the eye is larger than this value. The OQAS also incorporates a modified Thorner optometer, formed by 2 achromatic doublets, used to compensate the patient's spherical refraction. By moving 1 of the doublets, it is possible to correct the ametropia. The system automatically obtains the condition that corresponds to best focus condition, and therefore the measurements performed are not affected for the ametropia of the patient.

From the PSF images, the MTF that yields the relationship between the contrast of an object and its associated image as a function of spatial frequency was obtained by computing the modulus of the 2-dimensional Fourier transformation of the PSF. The 1-dimensional MTF was calculated as the radial projection (the mean overall orientations) of the 2-dimensional MTF.

Measurements were done with a 5 mm pupil. Different curves of MTF were not compared; instead, the spatial frequency at 0.5 MTF and 0.1 MTF were analyzed. Data at 0.5 MTF represent the spatial frequency cycles per degree (cpd) at which the image contrast is degraded 50% compared to the object contrast. Data at 0.1 MTF represent the spatial frequency in which the image contrast is degraded 90% compared to the object contrast and corresponds to the maximum resolution of the optical system.

### Data Analysis

Analyses were performed using SPSS 11.0 for Windows. All values are presented as means ± SDs. The comparison between the conventional and MICS IOLs was established by the Mann-Whitney *U* test with 2 independent samples. A level of significance of $\alpha = 0.05$ (2 tailed) was used in this study.

## RESULTS

Table 1 shows the characteristics and MTF results of the 3 IOLs. Figure 1 presents the 0.5 MTF and 0.1 MTF values.

Statistical analyses with Mann-Whitney *U* test did not show significant differences in 0.5 MTF and 0.1 MTF between the conventional and the MICS IOLs. At 0.5 MTF, differences were not statistically significant between the AcrySof and UltraChoice 1.0 ($U = 38$; $P = .825$) or for the AcrySof BM and Acri.Smart ($U = 20$; $P = .070$). At 0.1 MTF, statistical significance was not found between AcrySof and UltraChoice or Acri.Smart ($U = 40$, $P = .965$, and $U = 21$, $P = .085$, respectively).

## DISCUSSION

The optical quality of the eye is degraded because of diffraction at the pupil margin, defocus, light scattering, and eye aberrations. The crystalline lens induces aberrations and scattering, which degrades the quality of the image on the retina. After cataract extraction and implantation of the IOL, the optical quality of the eye will also be affected by aberrations and scattering induced by the IOLs implanted. These aberrations depend on 2 characteristics of the lens, thickness and surface quality, and will vary depending on the type of IOL implanted. Precise and careful processing can reduce optical aberrations, but never to achieve a zero-point. Theoretically, lenses can be infinitely thin and without aberrations and thus have an MTF of 1. However, proper lenses all have an actual thickness and MTF values generally decrease as lens thickness increases. The fabrication of a lens design as close as possible to the theoretically infinite thin lens is limited by the refractive index of the material from which the lens is made.[8] Poly(methyl methacrylate) and hydrophilic acrylic are used nowadays to produce the thinnest lenses.

The type of IOL implanted depends on the surgical technique, patient, and surgeon's choice. Microincision cataract surgery implies the use of lenses that could be implanted through a 1.5 mm incision to prevent SIA. The 2 MICS IOLs used in this study were the UltraChoice 1.0, which is a rollable IOL, and the Acri.Smart 48S, which is injected under high pressure with the aid of an hydraulic injector; thus, the main point of these IOLs is in the way they affect the optical quality of the eye in vivo.

The MTF was evaluated for 2 IOLs for MICS and for a conventional IOL (incision 3.2 mm). Although this bigger incision produces a higher SIA than the 1.5 mm incision for MICS, a comparison between MICS lenses and the conventional lens is still possible. This is because the MTF studied by OQAS depends only on scattering and aberrations and not on ametropia.

Considering that thin lenses are supposed to have better MTF in vitro results than thicker IOLs, a better MTF for a thin IOL was expected, but was not the case. No

**Table 1.** The IOL characteristics and MTF values.

| IOL Type | Incision Size (mm) | IOL Power (D) (Mean ± SD) | Defocus Equivalent (D) Postoperative (Mean ± SD) | BCVA Postoperative (Mean) | Spatial Frequency (cpd) at 0.5 MTF (Mean ± SD) | Spatial Frequency (cpd) at 0.1 MTF (Mean ± SD) |
|---|---|---|---|---|---|---|
| Alcon MA60BM | 3.2 | 19.86 ± 6.21 | 1.13 ± 0.72 | 20/20 | 2.647 ± 0.833 | 8.720 ± 3.074 |
| UltraChoice 1.0 | 1.6–1.8 | 20.39 ± 1.05 | 0.88 ± 0.35 | 20/20 | 2.601 ± 0.986 | 8.814 ± 4.380 |
| Acri.Smart 48S | 1.6–1.8 | 23.25 ± 4.60 | 1.00 ± 0.63 | 20/20 | 3.453 ± 0.778 | 11.418 ± 2.574 |

BCVA = best corrected visual acuity; cpd = cycles per degree; IOL = intraocular lens; MTF = modulation transfer function

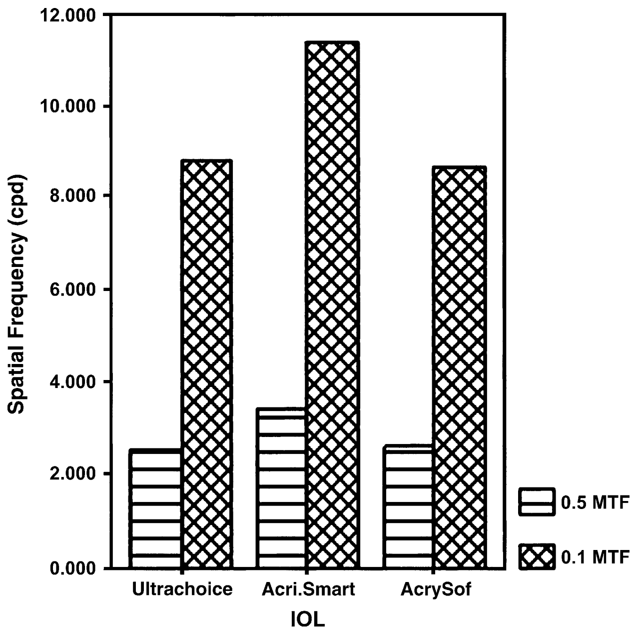


**Figure 1.** Spatial frequency (cpd) for 0.5 MTF and 0.1 MTF.

statistically significant difference was found at 0.5 MTF and 0.1 MTF between the conventional and MICS IOLs. Nevertheless, MTF measured in vivo not only depends on the aberrations of the IOL but also on the tear film and anterior and posterior corneal surface aberrations. The results of this study agree with previous published data about the spatial frequency in which the MTF falls to 0.5 and 0.1, using the same double-pass method in patients implanted with IOLs, and the OQAS is the same system used in this study.[9]

In a young eye, the corneal and crystalline lens aberrations tend to cancel each other (an example of coupling of 2 optical systems). Hence, the ideal IOL would not yield low optical aberrations but also be able to compensate for corneal aberrations, just like the natural crystalline lens. Such a lens would be responsible for a reduction in the total high-order ocular aberrations and an improvement in the optical quality of the eye. However, it needs to be considered that the visual quality of patients implanted with IOLs comes from the optical quality of the IOL and the neural processing. Therefore, visual acuity and contrast sensitivity measurements should be correlated with the findings in this study. Future studies will be addressed in this area to fully document the visual quality of patients in whom IOLs were implanted.

In conclusion, MICS IOLs show excellent MTF performance but no significant difference in MTF between conventional and MICS IOLs in this study were found. The evaluation of MTF in vivo may be the best method to study the optical quality of eyes implanted with IOLs.

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