•. Jan-Mar 2015;8(1):2-11
doi: 10.1016/j.optom.2014.12.001. Epub 2015 Jan 7.

JENVIS VISION RESEARCH JENA

Ernst-Abbe-Hochschule Jena
University of Applied Sciences

Measurement of the imaging quality of three intraocular lenses using the VirtIOL device

Authors: Lena Petzold [1], Sebastian Marx [2], Wolfgang Sickenberger [1,2],
Affiliations: [1] Ernst Abbe University of Applied Science Jena, Germany
[2] JENVIS Research c/o Ernst Abbe University Jena, Germany

Introduction:

The development of an intraocular lens (IOL) starts using software-based modeling, according to expected patient needs, and, in a second step, using manufacturing know-how and developing eye models [1]. The evolved IOLs must then undergo various testing steps, like clinical studies or *in vitro* measurements to be approved for use at patients. Standard *in vitro* IOL tests use artificial eye models to understand optical performance. There are many assumptions [2] in these simulations, however the tests are relatively easy to conduct and require significantly fewer resources than clinical studies. Especially during the corona pandemic, it was difficult to examine patients throughout clinical trials. In order to generate an objective test set up to avoid using subjects, a camera was used instead of the patient's eye. The technique here describes how an IOL is encapsulated in an artificial wet eye cell and is optically transferred by the optical system of the VirtIOL in the plane of the entrance pupil of the used camera set up.

Purpose:

The primary objective was to evaluate the imaging quality of three different intraocular lenses with the VirtIOL device. Secondary objective was to investigate the contrast sensitivity in this *in vitro* setting.

Methods:

The data were obtained by *in vitro* measurements with the VirtIOL device. The VirtIOL is a compact optical bench system; essential features are a table mounted device that allows a subject or a camera to view through an IOL along the optical axis (Figure 1) onto a target in any given distance. The technique is called "Virtual Implantation", because the IOL is not surgically implanted in the eye but is, nevertheless, functioning at the entrance pupil plane of either the patient's eye or an objective image capturing system with the VirtIOL. In this *in vitro* setup an industrial camera (UI3040CP-C-HQ Rev.2, IDS, Germany) was mounted on the chin rest of the VirtIOL device to detect the 1951 USAF resolution test chart (Edmund Optics, USA) with a size of 3 inches.

Figure 1: Parts of the VirtIOL device

The three different IOL types (Table 1) were encapsulated in the wet cell of the artificial model eye (Figure 2) and alternately inserted into the VirtIOL device.

Table 1: Designation of the tested IOL types

No.	IOL type	Manufacturer
IOL 1	monofocal	Carl Zeiss Meditec, Germany "CT SPHERIS 209M"
IOL 2	trifocal	Carl Zeiss Meditec, Germany "AT LISA tri 839MP"
IOL 3	EDOF	Teleon Surgical, Germany "ACUNEX VARIO AN6V"

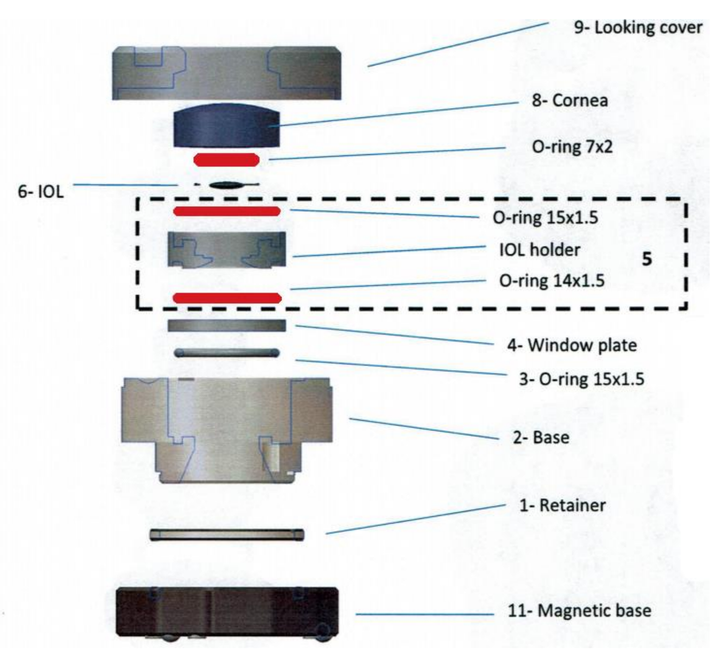

Figure 2: Model eye construction // source: manufacturer (10LENS S.L.U.)

Three modules were used within the setup: (1) a height adjustable table with the VirtIOL device with the (2) camera set-up including a computer and (3) a movable illumination cabinet with the USAF test chart (Figure 3).

During the measurements of the resolution and the contrast value of each IOL, the test chart was presented at distances of 6 m, 1m and 0.4m. At the respective distances, the test pattern is detected by the VirtIOL via the camera sensor and displayed vis the software "uEye Cockpit" (v4.95, IDS, Germany). The resolution in line pairs per millimeter [lp/mm] was determined using the number of the reached group.
The images, which have been captured by the software were also used to determine the contrast values. Twenty repetitions of the contrast measuring were made at a VirtIOL system aperture of 3 mm to simulate photopic light conditions. A descriptive statistic and when applicable an ANOVA tested was performed.

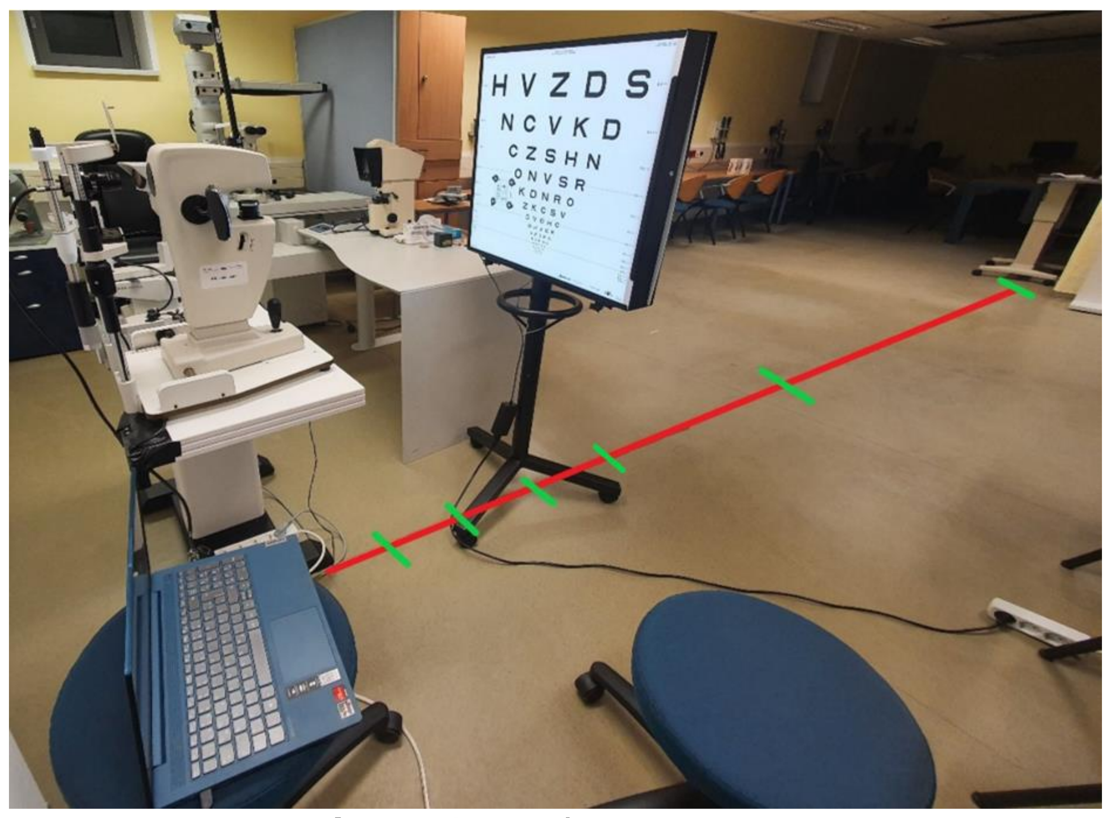

Figure 3: *In vitro* test set up

Results:

Table 2: Resolution in line pairs per mm [lp/mm] within the measured intraocular-lenses for defined distances d

d [m]	Monofocal IOL	Trifocal IOL	EDOF IOL
6.0	0.45 lp/mm	0.45 lp/mm	0.45 lp/mm
1.0	1.00 lp/mm	2.83 lp/mm	2.52 lp/mm
0.4	1.00 lp/mm	3.56 lp/mm	1.12 lp/mm

Table 3: Mean contrast values and standard deviations of measured IOLs at defined distances d in meter

d [m]	Monofocal IOL	Trifocal IOL	EDOF IOL	p
6.0	236.0 ± 8.1	115.0 ± 2.5	123.0 ± 3.9	<0.001
1.0	95.65 ± 1.57	75.30 ± 1.26	81.45 ± 1.276	<0.001
0.4	36.0 ± 0.0	42 ± 0.7	36 ± 0.4	<0.001

The monofocal lens attained the best imaging quality at a distance of 6 m, whereas the multifocal lenses dominated the intermediate and near range. In direct comparison, the trifocal lens performed better at the latter distance of 1 m than the EDOF lens, which generated a higher imaging quality at distance (Table 2).

Discussion:

All IOLs achieved the same resolution at distance. Following the literature, it is shown that the monofocal IOL should attain a higher resolution than the multifocal intraocular lenses [3]. A potentially reason is the decreased resolving power of the used camera. By using another camera with a higher resolution the resulting values may can be more accurate.

Conclusion:

The three IOLs performed differently, except the resolution at a distance of 6m. The contrast values decreased continuously with increasing resolution and declining distance for all three IOLs types. However, the generated results are influenced by the limited resolution of the used measuring camera, which is comparable to a VA of 20/10. With the defined VirtIOL *in vitro* setup, the work represents a basis for further evaluations of intraocular lenses with the VirtIOL device including humans for a preclinical evaluation prior real implantations.

References:

1 Rosales P, Marcos S. Customized computer models of eyes with intraocular lenses. Optics express 2007;15(5):2204-2218.
2 Gatinel D, et al Determining the Theoretical Effective Lens Position of Thick Intraocular Lenses for Machine Learning-Based IOL Power Calculation and Simulation. Trans. Vis. Sci. Tech. 2021;10(4):27.
3 Son, Hyeck Soo et al.(2020): Ray propagation imaging and optical quality evaluation of different intraocular lens models. In: PloS one 15 (2), e0228342.

contact: jenvis-research.com | Address: JENVIS Research Institute • c/o Ernst Abbe University of Applied Sciences Jena • Carl-Zeiss-Promenade 2 • 07745 Jena • Germany | Phone: 0049-(0)3641-205871 |E-Mail: info@jenvis-research.com