• Letter to the Editor •

A direct observation of aqueous humour flow *in vivo* after implantable collamer lens with a central hole implantation

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Dear Editor,

We present the reported case of the aqueous humour flow observed *in vivo* after implantable collamer lens (ICL) with a central hole implantation surgery. ICL, a phakic intraocular lens which is located in the posterior chamber, is an effective treatment to correct moderate-to-high myopia[1-2]. Although ICL implantation has advantages in terms of safety, efficacy, predictability, and stability, the impact of this procedure on aqueous humour dynamics remains unclear[3]. Secondary glaucoma and cataracts are the main complications of the ICL implantation surgery[4], which is thought to result from impairment of aqueous humour circulation after ICL implantation[5-6]. The new EVO Visian ICL (Figure 1; STAAR Surgical, Monrovia, CA, USA) with a central hole (0.36 mm in diameter) was approved by the China Food and Drug Administration in September 2014 and has been administered to over 10 000 patients. The application of central hole is believed to help the aqueous humour circulation after implantation in theory and was tested in animal models. However, the aqueous humour is transparent and hard to trace in living human. The aqueous humour circulation after ICL implantation still lacks direct evidence. The present case described the observation of aqueous humour flow *in vivo* after EVO Visian ICL implantation surgery. We obtained the written informed consent from the patient, and this case study is in accordance with the tenets of the Declaration of Helsinki.

A 30-year-old female complained of mild vision blurring in the left eye and was diagnosed with "iridocyclitis" at postoperative 2wk after bilateral spherical ICL with a central hole implantation for high myopic correction. The lenses, made with a biocompatible polymer material called collamer, were -11.00 D for OD and -10.50 D for OS in power, and 13.2 mm in length. The preoperative and 1-week postoperative data are presented in Tables 1 and 2, respectively.

The uncorrected distance visual acuity (UDVA) in the left eye was 20/20 and the intraocular pressure (IOP) was 12 mm Hg. A slit-lamp examination (YZ5T Slit Lamp Microscope Image Processing System; 66 Vision-Tech Co., Suzhou, China) without the pupil dilated showed anterior chamber inflammation, and the grading of the aqueous flare was 4+. These cells and the flare existing in the aqueous humour, like a "tracer," clearly showed the movement of the aqueous humour. During this period, the aqueous humour could be observed with an intense flare emerged and resubmerged *via* the central hole in a way similar to a "tide phenomenon" (Video 1 taken by built-in 3CCD camera with oblique illumination; online supplementary), and the trajectory of the aqueous humour movement was "a gush and a partial reflux". The aqueous humour from the posterior chamber passed through the central hole into the anterior chamber quickly, and it returned to the posterior chamber with a slightly decreased speed (Figure 2).

Tobramycin-dexamethasone eye drops were used topically six times a day for 1d in the left eye, and then four times a day for 7d. When the patient visited our clinic again, she had no complaints, UDVA was 20/20 in the left eye, the aqueous flare disappeared from the anterior chamber, and the aqueous humour became transparent in the left eye. This patient demonstrated a good prognosis after the 8-month follow-up exam.

The most interesting finding in this case is the presence of cells and flare, which allowed the visualization of the aqueous humour flow dynamics *in vivo* after EVO visian ICL implantation. This might be the first direct observation of the special aqueous humour flow mode after the central hole ICL implantation.

Figure 1 The EVO Visian ICLs with a central artificial hole.

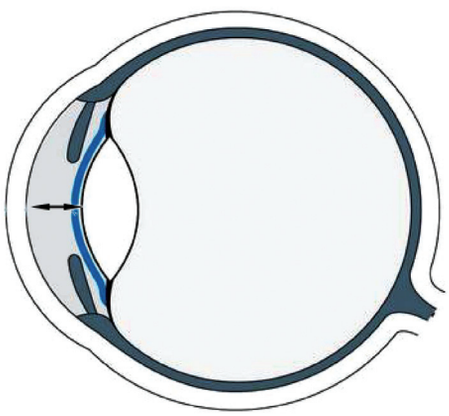

Figure 2 The blue line shows the location of the EVO Visian implantable collamer lens in the posterior chamber The arrow shows the aqueous humour outflow and inflow through the central hole into the anterior chamber.

Table 1 Preoperative characteristics

Characteristics	OD	OS
Manifest refraction	-9.50/-0.50×170	-9.25/-1.00×170
CDVA	20/20	20/20
IOP, mm Hg	14.7	14.9
ACD, mm	3.67	3.50
Central corneal thickness, μm	477	482
Axial length, mm	27.10	26.33
White-to-white, mm	11.8	11.8
Endothelial cell density, cells/mm^2	2978	2731

CDVA: Corrected distance visual acuity; ACD: Anterior chamber depth; IOP: Intraocular pressure.

Table 2 Characteristics 1wk after surgery

Characteristics	OD	OS
Manifest refraction	+0.50 /-1.00×155	+0.50/-1.00×170
CDVA	20/16	20/20
IOP, mm Hg	14.1	12.2
ACD, mm	3.57	3.38
Vault, μm	670	650

CDVA: Corrected distance visual acuity; IOP: Intraocular pressure; ACD: Anterior chamber depth.

ICL has many advantages in correcting refractive error[7–10]. The latest-generation EVO Visian ICL with the CentraFlow design is believed to improve aqueous humour circulation due to a central artificial hole in the ICL (Figure 1). Fujisawa *et al*[6] found that long-term aqueous humour circulation disorder after traditional ICL implantation could lead to a characteristic change in crystalline lens epithelial cells, while neither cataract nor changes in lens epithelial cells were found after central hole ICL implantation. They proposed the hypothesis that the outflow of aqueous humour is cut off in midstream in the conventional ICL, so the aqueous humour in the posterior chamber can hardly flow into the anterior chamber in the long-axis direction. The aqueous humour has to flow over the edge of ICL and enter the anterior chamber through the pupil in short-axis direction. Differently, the central hole in ICL allows the communication between the anterior and posterior chamber in the central pupil area as in the natural circumstances. Fujisawa *et al*[6] revealed the importance of aqueous flow in the space between the ICL and the crystalline lens to prevent cataract. However, the central hole was 0.36 mm diameter in their experiment and shape of the anterior chamber in the porcine eyes is different from that of human eyes. There has been no direct observation of the aqueous humour flow *in vivo* in human eyes. Moreover, the 0.36 mm diameter central hole in ICL has no optical effect. Whether the smaller central hole in EVO ICL has the same effect still needs further investigation.

There are numerous publications describing visual outcomes[11] and post-surgical complications[12] in patients treated with the EVO Visian ICL in the past 3y, the *in vivo* aqueous flow with the EVO Visian ICL has not yet been specifically described. In this case, we observed the *in vivo* aqueous humour dynamics in which the aqueous humour from the posterior chamber passed through the central hole into the anterior chamber quickly, and then it partially returned to the posterior chamber with a slightly decreased speed. This direct observation of aqueous humour flow in the central hole indicates the aqueous humour circulation in the space between the posterior chamber and the anterior chamber, which is strong support to the hypothesis of Fujisawa *et al*[6]. Interestingly, the aqueous humour flow in the central hole area has a characteristic tide mode. The quick outflow from the central hole might be due to the differential pressure between the posterior and the anterior chamber. The constant production of aqueous humour from the ciliary body increases the pressure of the posterior body. Once the pressure is beyond that of the anterior chamber, the aqueous humour erupts into the anterior chamber through the central hole. The overflow of the aqueous humour then induces the reflux back to the posterior chamber after every outflow eruption due to inertia. Implantation of the EVO Visian ICL effectively makes the aqueous humour flow from the posterior chamber through the central hole into the anterior chamber, which is more in line with the physiological state of aqueous humour circulation, provides the nutrition to the anterior surface of crystalline lens. This is the key to prevent cataract after the ICL implantation,

although the impact of the tide mode of aqueous humour still needs further investigation.

This case makes us to directly observe the characteristic tide-mode aqueous flow from the central hole of the EVO ICL *in vivo*, indicating aqueous humour circulation in the space between the posterior and the anterior chamber. This might add important evidence to the study of aqueous humour circulation after EVO ICL.

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