Intraocular lens extraction using the cartridge pull-through technique

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Abstract

Current intraocular lens (IOL) explantation techniques are limited to cutting the optic and removing the pieces through a small incision, or folding single piece acrylic IOLs using a two-handed technique. Poor execution of IOL explantation can result in injury to intraocular structures, including the corneal endothelium and iris. The minimally invasive “cartridge pull-through technique” was invented, using a cartridge for IOL implantation and novel forceps optimized for secure grasping of the IOL for removal. This method involved less manipulation in the anterior chamber, thereby reducing the risks of complications such as corneal and iris injuries. A “dropped IOL” lying on the retinal surface can be extracted directly without lifting it onto the iris first. The cartridge-pull through technique offers a more streamlined and potentially safer approach for IOL explantation.
Longer life spans and crystalline lens extractions in younger patients have increased the duration of intraocular lens (IOL) implantation in many patients. These changes are also increasing the number of patients with IOL dislocation, which can be treated by IOL extraction, vitrectomy, intrascleral IOL fixation and suturing, or a combination of these treatments. More recently, intrascleral fixation has become widely used for IOL fixation, and many reports have focused on the techniques and outcomes of this method.\textsuperscript{1-3} However, few reports have provided detailed information on IOL explantation, despite it being performed in most of these surgeries.\textsuperscript{4-7} Currently, there are two methods of IOL extraction: folding of the IOL into half with forceps, and cutting it into several pieces with scissors before removal.\textsuperscript{8} Both maneuvers must be performed within the narrow space of the anterior chamber and can cause corneal endothelial cell loss, iris injury, or anterior chamber hemorrhage.\textsuperscript{9-11} In addition, small debris that remains in the eye during IOL extraction can result in the loss of intraocular tissue, making IOL extraction a highly invasive procedure.

In recent years, cases of cataract surgery for refractive correction have increased. However, postoperative refractive error or dissatisfaction with multifocal-IOL implantation outcomes can lead to a need for IOL extraction. Furthermore, when the purpose of primary surgery is refractive correction, good postoperative visual function can be achieved with a reoperation, which requires preservation of the lens capsule and a small incision for extracting the IOL to prevent induced astigmatism.
This study aimed to present the minimally invasive “cartridge pull-through technique” using a cartridge for IOL implantation and novel forceps optimized for obtaining a secure grasp of the IOL for removal; the clinical application of the technique has also been presented. The cartridge used to extract the IOL is used off-label, and was originally intended for insertion of the IOL.

**Surgical Technique**

The study and surgery were conducted in conformance with the tenets of the Declaration of Helsinki, and was approved by the ethics committee of the Tane Memorial Eye Hospital. Written informed consent for participating in this study was obtained from all patients before they underwent the surgery.

In the preparation for IOL extraction, the anterior chamber is filled with ophthalmic viscoelastic substance (OVD) at room temperature. When replacing the IOL, it is removed from the lens capsule and pulled up on top of the iris. In the case of IOL dislocation, the vitreous body around the IOL is dissected using a vitreous cutter or a viscoelastic substance; the IOL is then pulled up on top of the iris. In order to grasp the optics slightly to the right of the base of the haptics in the IOL, the IOL must be adjusted with a Sinskey hook to a position over the iris where it can be easily grasped with extraction forceps.

The cartridge pull-through technique uses a D1 cartridge (Hoya Co., Ltd.) and Fukuoka’s
IOL extraction forceps (Handaya Co., Ltd.) (Fig. 1). A sclerocorneal incision of 3.2 mm or wider is created; the cartridge lumen is filled with an OVD, after which the forceps are inserted until their tip is exposed from the cartridge end (Fig. 2A, a). The forceps are then inserted into the anterior chamber to grasp the optic slightly to the right of the base of the haptics (Fig. 2B, b). With the other hand, the cartridge tip is advanced slowly into the anterior chamber through the incision in the bevel down position and maintained steady (Fig. 2C, c), while the forceps grasping the IOL is retracted to draw the latter into the cartridge (Fig. 2D, d). The tip of the cartridge must be kept inside the anterior chamber until the IOL optic rolls up and into the barrel of the cartridge as it is pulled into the latter. The cartridge and forceps are then pulled out of the anterior chamber together to extract the IOL (Fig. 2E, e and F, f) (Video 1, http://links.lww.com/JRS/A380).

The extraction is performed according to the method outlined above for IOL exchange by preserving the lens capsule, or when a dislocated IOL is close to the iris. A “dropped IOL” lying on the retinal surface can be lifted up to the back of the iris with vitreous forceps after vitrectomy, and can be extracted directly from the vitreous cavity without first pulling it on top of the iris (Fig. 3) (Video 2, http://links.lww.com/JRS/A381). The IOL, which is lifted to the back of the iris using vitreous forceps, is rarely positioned for grasping with extraction forceps; the IOL optics are adjusted several times using a set of forceps in each hand. This adjustment is repeated until the IOL is at the ideal position for grasping with extraction
forceps. The procedure should be performed with intraocular irrigation through an infusion port if there is a risk of globe instability.

The following information and points of caution should be considered when performing the cartridge pull-through technique:

- A corneal incision can be made if the extracted IOL is confirmed to be a foldable IOL; however, if the dislocated IOL type is unknown preoperatively, a scleral tunnel incision should be made in case the IOL is intraoperatively determined to be composed of polymethylmethacrylate (PMMA). In addition, if the internal incision is close to the iris, the latter may be caught in the cartridge; therefore, an internal incision must be created away from the iris.

- The D1 cartridge is suitable for implantation of IOL with an optic diameter of 6.5 mm. The recommended lengths of incision are 3.2 mm for corneal and 3.0 mm for sclerocorneal incisions. An incision wound of this size allows extraction of a foldable 6.0-mm optic diameter IOL to pass through the cartridge. However, the recommended incision wound size is a tight fit for simultaneous passage of the forceps grasping the optic and loop through the cartridge for IOL extraction; this explains the recommended sclerocorneal incision of 3.2 mm or wider.

- When the extracted IOL is expected to be of high power or low refractive index and thickness, the cartridge should be warmed in a warming cabinet before use to promote
stretchability; in addition, incisions should be made on the cartridge tip to enlarge the opening diameter.

- Various OVDs can be used. As a cooled OVD will harden the IOL, rendering it difficult to extract, OVDs should be warmed to room temperature. The cartridge needs to be filled with OVD for the procedure, because cartridges inserted in the anterior chamber without OVD will result in iris incarceration in the cartridge lumen. Furthermore, an OVD lubricates the cartridge lumen.

- A non-foldable IOL made of hard materials such as PMMA cannot be extracted using this method.

- Retinal detachment may occur when the vitreous body is tangled on the IOL and pulled out together with it during IOL extraction; therefore, an OVD and vitreous cutter are required for dissecting the vitreous body before extraction.

- Before performing this procedure, it is important to understand the movement of the IOL as it is pulled into the cartridge with forceps (Video 3,http://links.lww.com/JRS/A382). If the cartridge is beveled down, the IOL optics will fold and bulge out. Furthermore, the behavior of the haptics varies depending on the grasped portion of the IOL optic (Fig. 4). If the grasped portion of the optic is slightly to the right of the base of the haptic, the nearest haptic is immediately pulled into the cartridge along with forceps. The furthest haptics actually turn up and toward the cornea as the IOL is being pulled into the
cartridge. The barrel of the cartridge needs to be rotated so that the leading haptic stays away from the cornea. The behavior of only the one leading haptic may be checked to make the extraction easy to control. (Figure 4A, a). If the intermediate optic of both haptics has been grasped, caution is necessary; both haptics will rise to the vitreous side. If the IOL is removed when the haptics are still outside the cartridge, this may damage the iris (or lens capsule in case of IOL replacement). In addition, as it cannot be confirmed whether the loop is hidden behind the cartridge, it is difficult to decide whether the maneuver is safe. Therefore, grasping the optic at the midpoint is incorrect, and can lead to iris (or capsule) trauma; it cannot be recommended. (Figure 4B). Caution is necessary during extraction, and the procedure must be performed slowly while checking the behavior of the IOL pulled into the cartridge.

Results
A total of 16 eyes with IOL dislocation that underwent IOL extraction + vitrectomy + intrascleral IOL fixation with a D1 cartridge and Fukuoka’s IOL extraction forceps between July 2019 and March 2020 at our hospital were included. Data regarding the patient background, preoperative and postoperative corrected distance visual acuity (CDVA), preoperative and postoperative corneal endothelial cell density, and type of the extracted IOL are shown in Table 1. There were no patients whose visual acuity worsened postoperatively;
the IOL could be extracted with this technique in all patients. The extracted IOLs were three-piece IOLs in 10 eyes and single-piece IOL in 6 eyes. There were no complications such as iris injury, corneal endothelial cell loss, anterior chamber hemorrhage, or postoperative endophthalmitis.

Discussion

Herein, we described the “cartridge pull-through technique,” which was developed for IOL explantation, and the results of the procedure in 16 patients. The technique uses a cartridge for IOL implantation and forceps optimized for securely grasping the IOL for its removal. Bhaumik and Mitra\(^4\) used a cartridge (Alcon Laboratories, Inc.), wire snare, and reported that minimally invasive IOL extraction was possible through a small 3.5-mm corneal or limbal wound. However, the snare must be custom-made from a wire, and only single-piece IOLs can be extracted with this method. The twist and out explantation technique proposed by Pandit et al.\(^7\) also allows removal of a foldable IOL via a 2.2 mm incision. However, this method requires rolling of the IOL, that is twisted around the forceps in the narrow anterior chamber. As the IOL tries to spread to its original state, we believe that it may be difficult to keep the IOL rolled.

Our hospital has been performing IOL extraction using the cartridge pull-through technique since June 2018. Early in the development of this technique, the D1 cartridge and Zaldivar-
Kraff ICL PACman forceps (ASICO LLC) for surgery of implantable collamer lens (STAAR Surgical AG) were used. Extraction of many single- and three-piece IOLs was possible with these devices. However, the jaws of the PACman forceps were too wide to glide smoothly in the cartridge lumen and too short to provide sufficient grasping power. As a result, thick IOLs could not be removed occasionally, and hydrophilic IOLs were too slippery to be extracted. This led to the development of Fukuoka’s IOL extraction forceps, which have a narrow and extended tip with hollow jaws to release pressure, and are serrated for improved grip. These modifications have enabled stable grasp across the center of the IOL optic.

Before clinical use of the new forceps, an IOL extraction experiment was performed in water at the same temperature (29 to 32 degrees) as that of the anterior chamber water. Three of each type of IOLs were extracted: MA60AC (Alcon Laboratories, Inc), SN60WF (Alcon Laboratories, Inc), ZCB00 (Johnson & Johnson Vision Care, Inc), KS-SP (NIDEC Corporation Ltd/ STAAR Surgical AG), and Lentis Mplus (Oculentis GmbH). As these were practice IOLs, the power of each IOL were unknown. The experimental results showed that all three Lentis Mplus lenses could not be extracted; however, all other IOLs were successfully extracted. Since it is not possible to perform the experiment using lenses at every IOL power, the range of frequency of successful extraction is unknown. In actual clinical practice, all 16 foldable IOLs used in this study were successfully extracted; and most of the frequently used IOLs can be extracted by this method. Furthermore, although there has been
no opportunity in clinical practice to extract hydrophilic IOLs, an experiment was performed where a hydrophilic IOL was extracted in the same manner as described. Although the Lentis Mplus could be grasped, it could not be pulled into the cartridge because of its large volume, as it is of the plate type. The Micro F® (FINE VISION) could be firmly grasped and extracted easily. Switching from the PACman to Fukuoka’s forceps has made it easier to perform various IOL extractions.

There were 2 cases of dropped IOL on the retinal surface among the 16 eyes. In these two patients, the dropped IOLs were extracted directly from the vitreous cavity. In our IOL explantations performed using the conventional method, dropped IOLs were first placed on the iris before extraction, but pulling up onto the iris failed in some cases, resulting in multiple drops in this step. Repeated attempts to retrieve a dropped IOL may damage the retina. Thus, direct IOL extraction from the vitreous cavity according to this method provides the additional benefits of protecting the anterior chamber tissue and suppressing retinal invasion.

No serious complications were noted in this study. The reason for this is that the use of a cartridge makes the incision smaller, and the pressure difference between the anterior chamber and the outside is small; this makes it difficult for the iris and vitreous to escape during IOL removal. In addition, it is possible to further reduce the wear of endothelial cells and iris by devising the angle of the wound opening and the direction of the bevel of the
cartridge. However, since the cartridge being used is not made specifically for IOL extraction, the entire IOL cannot be pulled in; the haptics therefore remain outside the cartridge. As such, there is a need to be careful to not damage the cornea or iris.

Unfortunately, after developing this technique, the D1 cartridge (outer diameter 2.25 mm) has been discontinued and is currently difficult to obtain. Next to the D1, the company's largest cartridges are C1 (for VA-60BB insertion) and C7 (for VA-70AD insertion); the tips of both cartridges have the same shape (outer diameter 2.13 mm). The recommended incisions are 3.0 mm in the cornea and 2.8 mm in the sclerocornea. In the same underwater experiment as mentioned above using Fukuoka's IOL extraction forceps and C1 and C7 cartridges, the same results were obtained as with the D1 cartridge. Currently, we are using commercially available cartridges for the procedure, but the development of a specialized extraction tool would be ideal for further fine-tuning of this technique.

In summary, the cartridge pull-through technique cannot be applied to extraction of all IOLs; however, it allows for effective foldable IOL extraction via an innovative minimally invasive procedure, with the potential of changing the future of IOL explantation.
Value Statement

WHAT WAS KNOWN

- Longer life spans and earlier ages for crystalline lens extraction have increased the duration of intraocular lens (IOL) implantation in many patients. These changes have led to an increase in the number of patients with IOL dislocation and the frequency of cases that require IOL extraction.

- There is an increase in the number of cataract surgeries performed for refractive correction. Postoperative refractive error or dissatisfaction with multifocal-IOL implantation outcomes can lead to a need for IOL extraction.

- Currently, IOL extraction requires folding the IOL into half with forceps or cutting it into several pieces with scissors before removal. Both maneuvers must be performed within the narrow space of the anterior chamber and can cause complications such as
iris or corneal injury; thus, IOL extraction is a highly invasive procedure.

WHAT THIS PAPER ADDS

- This minimally invasive method enables pulling of the IOL into the cartridge with forceps through a small wound to minimize intra-anterior chamber maneuvers, thereby offering a simple solution for IOL extraction.

- This method allows for direct extraction of the IOL dropped into the vitreous cavity without placement onto the iris, and is thus minimally invasive to tissues surrounding the anterior chamber.

Video 1-http://links.lww.com/JRS/A380

Video 2-http://links.lww.com/JRS/A381

Video 3-http://links.lww.com/JRS/A382

References


2. Yamane S, Sato S, Maruyama-Inoue M, Kadonosono K. Flanged intrascleral intraocular


Figure Legends

Figure 1. Cartridge and forceps used for the cartridge pull-through technique.

Top: D1 cartridge (Hoya Co., Ltd.). Bottom: Fukuoka’s intraocular lens (IOL) extraction forceps (Handaya Co. Ltd.)

Figure 2. Cartridge pull-through technique procedure.

A. The forceps are set so that they would pass through the cartridge, with the tip of the forceps protruding from its end.

B. The forceps held in the right hand is inserted into the anterior chamber to grasp the intraocular lens (IOL) optic. The optic is grasped slightly to the right of the base of the front loop.

C. The tip of the cartridge is slowly pushed into the anterior chamber with the left hand via the incision and fixed into position.

D. The IOL held with the forceps is pulled into the cartridge.

E. The IOL can be extracted when approximately half of the optic is pulled into the cartridge to form a cylindrical shape by pulling out the cartridge and forceps together (pulling in the entire IOL is ideal).

F. Successfully extracted IOL.
Figure 3. Direct extraction of the intraocular lens (IOL) from the vitreous cavity

Fallen IOLs can be extracted directly from the vitreous cavity without first lifting the IOL onto the iris.

Figure 4. Haptics behavior depending on the location of grasping the intraocular lens (IOL) optic.

A. If the optic is grasped slightly to the right of the haptics base, the furthest haptics actually turn up and toward the cornea. The barrel of the cartridge needs to be rotated so that the leading haptic stays away from the cornea.

B. If the optic is grasped in the midpoint between both haptics, they will rise to the vitreous side. If the IOL is removed while haptics are still outside the cartridge, the iris (or lens capsule in case of IOL replacement) may be damaged. In addition, it cannot be confirmed whether the loop is hidden behind the cartridge.
**Video Legend**

**Video 1.** Basic technique for intraocular lens (IOL) extraction using cartridge and forceps.

Two types of intraocular lenses (one-piece and three-piece) were extracted using this method.

The dislocated IOLs were extracted from close to the iris.

**Video 2.** Technique for intraocular lens (IOL) extraction directly from the vitreous cavity using cartridge and forceps

The IOL was dropped onto the retinal surface in 2 of 16 eyes; in both cases, the IOLs were removed directly from the vitreous cavity.

**Video 3.** The movement of the IOL as it is pulled into the cartridge with forceps

If the optic is grasped slightly to the right of the haptics base, the furthest haptics actually turn up and toward the cornea. The barrel of the cartridge needs to be rotated so that the leading haptic stays away from the cornea.

If the optic is grasped in the midpoint between both haptics, both haptics will rise to the vitreous side. As it cannot be confirmed whether the loop is hidden behind the cartridge, it is difficult to decide whether the maneuver is safe. Therefore, grasping the optic at the midpoint is incorrect, and can lead to iris (or capsule) trauma; it cannot be recommended.
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CDVA=corrected distance visual acuity; IOL= intraocular lens; Ave=average; SD=standard deviation.

*Alcon Laboratories, Inc. †Johnson & Johnson Vision Care, Inc. ‡NIDEC Corporation Ltd. §HOYA Corporation Ltd.