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New Instruments A Novel Short Intraocular Endoscope with Extended Depth of Focus: Evaluation of The Observation Field during Vitrectomy --Manuscript Draft--

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Alexander J. Brucker, MD
Editor-in-Chief
Retina

Dear Editor,
Dear Editor,

I am writing to submit our manuscript titled "**A Novel Short Intraocular Endoscope with Extended Depth of Focus: Evaluation of The Observation Field during Vitrectomy**" for consideration for publication in *Retina*. This study presents a newly developed intraocular endoscope with a short insertion length (10 mm), which significantly enhances the field of view during vitrectomy procedures compared to conventional endoscopes (30 mm). We believe that our findings offer a valuable contribution to the field, especially in terms of improving orientation and safety during vitrectomy, including robot-assisted surgeries.

In this study, we compared the newly developed short-insertion endoscope with conventional endoscopes in terms of the field of view, and we found that the new endoscope provided a significantly wider observation area around the optic disc and vortex veins. These advancements may have a direct impact on surgical efficiency and safety, particularly in complex cases with limited visibility, such as corneal opacity or retinal pathologies. We have also highlighted the potential for integrating this device in robot-assisted surgeries, further improving its clinical utility.

We believe that *Retina* is the ideal platform for our manuscript due to its focus on cutting-edge technologies in retinal surgery and its global readership. We have followed all ethical guidelines for conducting this study, and the work was approved by the Institutional Review Board of the National Hospital Organization Kyushu Medical Center (No. 22C105), in accordance with the Declaration of Helsinki.

This manuscript has not been published or presented elsewhere, in part or in entirety, and is not under consideration by another journal. All study participants provided informed consent, and the study design was approved by the appropriate ethics review board. We have reviewed your journal's policies, and we confirm that our manuscript adheres to all ethical and submission guidelines. All conflicts of interest are disclosed in the manuscript.

Thank you for considering our submission. We look forward to your feedback and hope that our manuscript will meet the standards of your esteemed journal.

Sincerely,

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New Instruments

A Novel Short Intraocular Endoscope with Extended Depth of Focus: Evaluation of The Observation Field during Vitrectomy

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Running Title: Wide-viewing short Intraocular endoscope

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Keywords: endoscopy; vitrectomy; robotics; robot surgery

Summary

We compared our newly developed intraocular endoscope with a short insertion length (10 mm) to a conventional model (30 mm) during vitrectomy. The short-insertion endoscope provided a significantly wider field of view around the optic disc and vortex veins. This improvement may enhance spatial orientation during vitrectomy, including in robot-assisted procedures.

Introduction

Intraocular endoscopes were first used in the 1930s for the removal of intraocular foreign bodies.¹ Initially, they had a diameter of 6.5 mm,² but with advancements in vitrectomy techniques, endoscopes as small as 1.7 mm were introduced.³ The subsequent development of 20-gauge endoscopes enabled intraocular imaging in a heads-up manner.⁴ Today, intraocular endoscopes are most commonly available in 23 or 25 gauge sizes.^{5,6}

Despite their advantages in visualizing structures such as the ciliary body, which are difficult to observe using wide-angle observation systems, intraocular endoscopes have several limitations.^{5,7,8} These include a narrow field of view, challenges with spatial orientation, and the requirement for handheld operation, which restrict their use primarily to cases with poor visibility, such as those involving corneal opacity.⁹

A wide observation area is essential for enhancing intraoperative safety and operability when surgeons manipulate an intraocular endoscope during vitrectomy. The newly developed intraocular endoscope with a short insertion length (OPO-25VDY-H; Medical Device Registration No.304AFBZX00088000) is designed with a 10 mm insertion length, which is considerably shorter than the 30 mm length of conventional intraocular endoscopes (VIT-25MFY-H; Medical Device Registration No. 225AFBZX00002000) (Figure 1). Furthermore, the working distance (WD) is 10mm or more, which is longer than the conventional models (typically 5mm or more). The short insertion length facilitates increasing the distance between the retina and the tip of the endoscope within the vitreous cavity, while the extended

WD allows for easier focusing even when this distance is relatively large. Consequently, an endoscope with a short insertion length is expected to enable observation from a more distant vantage point—providing a bird’s-eye-like view of the retina—and offer a wider angle of view.

This study compares the observation fields of the short-insertion and conventional intraocular endoscopes during vitrectomy to evaluate potential improvements in surgical safety and operability.

Methods

This retrospective, non-comparative case series was approved by the Institutional Review Board of the National Hospital Organization Kyushu Medical Center (approval No. 22C105) and was conducted in accordance with the Declaration of Helsinki.

Patient Population

The study included patients in whom both the optic disc and vortex veins were identifiable in fundus photographs and surgical videos. Patients who underwent vitrectomy between April 2022 and January 2023 were included, while those requiring reoperation were excluded. A total of 25 patients (25 eyes) were enrolled.

Surgical Technique

Surgery consisted of standard pars plana vitrectomy using a 25-gauge system. All patients underwent vitrectomy with posterior hyaloid dissection, epiretinal membrane removal when present, and internal limiting membrane (ILM) peeling with a minimum diameter of 2,500 μm . Brilliant blue G staining was used in all cases to assist ILM visualization, followed by a final fluid–air exchange. The brilliant blue G solution (Coomassie BBG 250; Sigma-Aldrich Co., St. Louis, MO, USA) was prepared at a concentration of 0.25 mg/mL in BSS Plus (Alcon, Fort Worth, TX, USA). Phacoemulsification with intraocular lens implantation was performed in all cataractous eyes.

Before concluding the surgery, both a conventional intraocular endoscope and the newly developed short-insertion endoscope were inserted through the superior temporal and superior nasal ports, respectively, to observe the peripheral retina.

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4 The optic disc was observed first, followed by inspection of the peripheral retina. If
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6 retinal degeneration or retinal tears were present, laser photocoagulation was
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8 performed at the discretion of the surgeon.
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10 11 **Quantitative Analysis of Optos Imaging** 12

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14 Color fundus images were obtained using an Optos California (Nikon, Tokyo,
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16 Japan). Macular-centered ultra-wide-field color fundus images were taken 1 day
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18 before surgery and 1 to 4 days postoperatively. Additionally, a video of the surgery,
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20 including a scene where the endoscope was used, was recorded. Optos Advance
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22 (Nikon, Tokyo, Japan) is the viewer software for Optos California, which allows for
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24 the measurement of areas within images. Wide-angle fundus photography with the
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26 Optos California creates a planar image from a spherical fundus, which can
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28 complicate accurate area measurement. In contrast, Optos Advance corrects for
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30 anatomical positioning and provides an area measurement of the fundus image
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32 that is anatomically accurate. The area of interest was calculated using a still
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34 image from the surgical video, specifically the moment when the optic disc and
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36 vortex veins were most clearly in focus, and by superimposing this area onto the
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38 corresponding wide-angle fundus photograph.
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Results

This study evaluated 25 eyes from 25 patients (15 men, 10 women; mean age, 66.5 ± 12.4 years; range, 49–90 years). The study included 11 right eyes and 14 left eyes. All patients underwent vitrectomy, including endoscopic observation, with insertion lengths of 10 mm and 30 mm. The average axial length was 24.2 ± 1.36 mm. The diseases included epiretinal membrane in nine eyes, vitreous hemorrhage in eight eyes, macular hole in three eyes, rhegmatogenous retinal detachment in two eyes, and vitreomacular traction syndrome, subretinal hemorrhage, and deviation of the intraocular lens in one eye each.

We first compared the observation fields using two types of endoscopes. The angle of view of the endoscope with a short insertion length (70.0 ± 2.30 mm²) was significantly wider than that of the endoscope with a longer insertion length (43.4 ± 3.66 mm²), centered on the optic disc ($n=25$, $p=8.08 \times 10^{-22}$) (Table 1). The observation range centered on the vortex vein was, on average, 68.9 ± 2.79 mm² and 44.6 ± 4.32 mm², respectively, with the short intraocular endoscope providing a significantly wider observation range than the conventional endoscope ($n=25$, $p=5.0 \times 10^{-18}$) (Table 1). Compared with the conventional endoscope, the short endoscope allowed for observation of $162 \pm 14\%$ more area around the optic disc and $156 \pm 16\%$ more area around the vortex vein.

Discussion

Unlike wide-viewing systems, which offer a bird's-eye perspective, intraocular endoscopes provide a lateral view, which is particularly useful in refractory cases such as corneal opacity.^{5,8} However, the use of endoscopes remains limited due to a steep learning curve and safety concerns.

This study demonstrated that the short-insertion endoscope (10 mm) provides a significantly wider field of view, which may help alleviate orientation challenges. Its longer working distance reduces the risk of retinal damage from excessive insertion. Additionally, the increased rigidity of the shorter endoscope enhances maneuverability. Importantly, despite its wider field of view, there were no instances of retinal contact.

Intraocular endoscopes enable visualization of the retina's periphery and the ciliary body without the need for scleral compression. While conventional models (30mm) have a limited field of view, the short-insertion endoscope (10mm) broadens this range, thereby enhancing its clinical utility.

This advancement may also benefit robot-assisted surgery. Various types of surgical support robots, including passive systems tailored for ophthalmic procedures, have been developed and evaluated.¹⁰ Among these, the OQrimo® intraocular endoscope-holding robot allows foot-switch-controlled visualization.^{11,12} Integrating a short-insertion endoscope may enhance its operability by offering a broader view. This wider field of view reduces the frequency of foot-switch adjustments needed during surgery, thereby improving overall usability and surgical efficiency.

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4 However, there are limitations. The extended working distance (≥ 10 mm) makes it
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6 challenging to focus on objects closer than 10 mm. In eyes with long axial lengths
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8 (>26.83 mm, the maximum in this study), maintaining focus may also be difficult.
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10 Forcing the endoscope tip closer to compensate could lead to unintended pressure
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12 at the insertion port.
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16 Additionally, the observed areas were measured visually by overlaying images in
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18 Optos Advance. This method may introduces potential measurement errors or
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20 biases.
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24 Our newly developed intraocular endoscope with a short insertion length
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26 significantly enhances the field of view compared to conventional models. This
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28 improvement may facilitate orientation and enhance safety during vitrectomy,
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30 including robot-assisted procedures.
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COI Discourse: Shintaro Nakao: Consulting fee by Boehringer Ingelheim, Chugai Pharmaceutical, Kowa, Novartis, Nipro, Riverfield; travel reimbursements and speaker fees from Alcon, Boehringer Ingelheim, Bayer Pharma, Canon, Chugai Pharmaceutical, JFC Sales Plan, Kowa, Mitsubishi-Tanabe pharma, Machida, MSD, Nipro, Novartis, Novo Nordisk Pharma, Otsuka, Santen Pharmaceutical, Senju Pharmaceutical, and Wakamoto Pharmaceutical. SN and K-HS hold patents on OQrimo.

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Figure Legend

Figure 1. Conventional intraocular endoscope and newly developed intraocular endoscope. (Top) The insertion length of conventional intraocular endoscope is 30 mm (arrow). (Bottom) The insertion length of the newly developed intraocular endoscope is 10 mm (dashed arrow).

Figure 2. Endoscopic images in fundus observation around the optic disc (A, B) and around the vortex vein (C, D). A and C show images observed using the conventional intraocular endoscope. B and D show images observed using the newly developed intraocular endoscope.

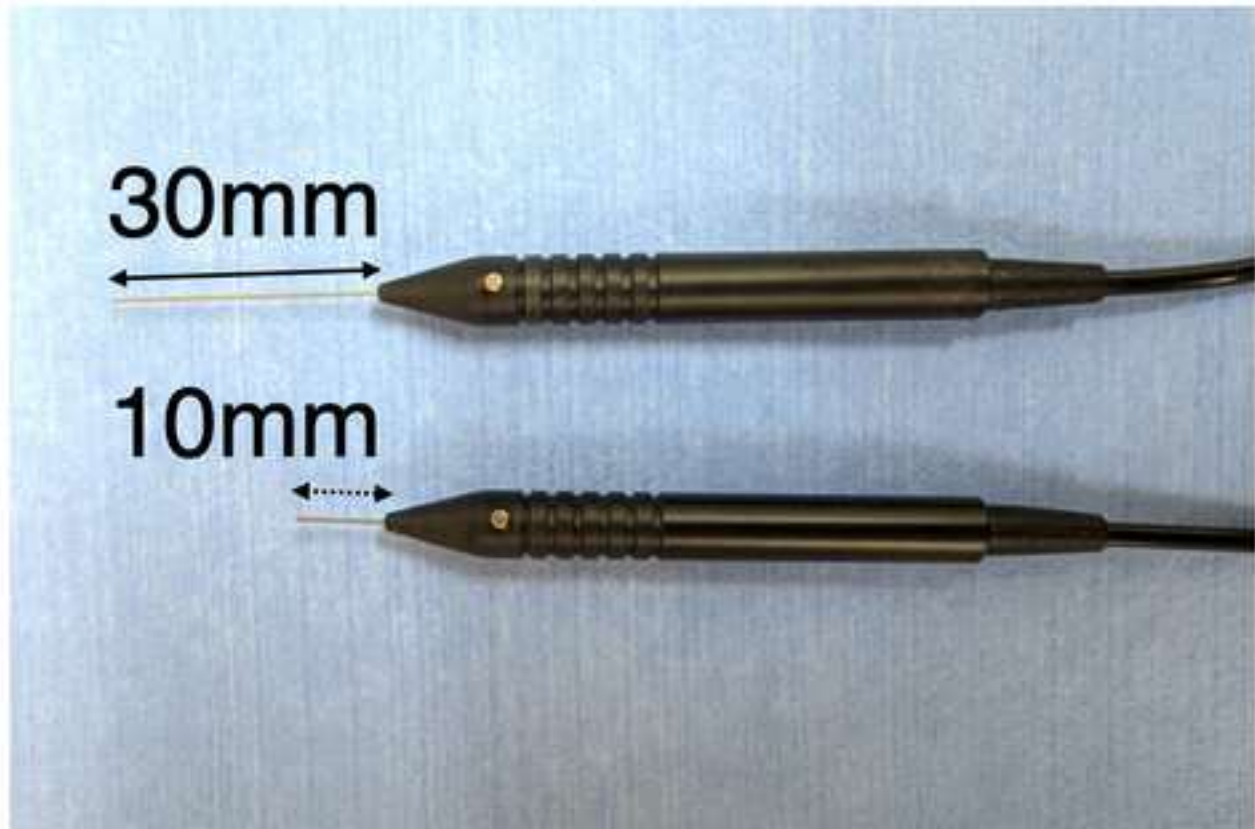


Figure 1

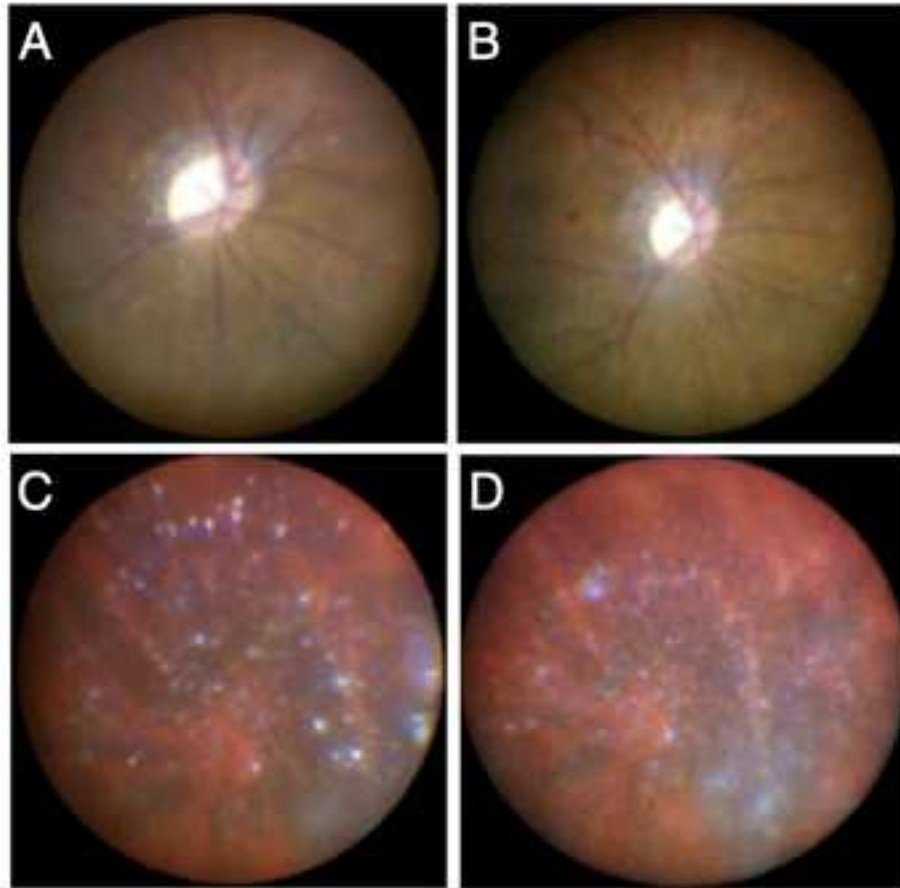


Figure 2



	Newly developed endoscope	Conventional endoscope	P
Observed area at optic disc (mm ²)	70.0±2.30	43.4±3.66	8.08x10 ⁻²²
Observed area at vortex vein (mm ²)	68.9±2.79	44.6±4.32	5.0x10 ⁻¹⁸

Table 1 Comparison of endoscopic angle of view