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New Fresnel lens loupe for nystagmus observation suitable for use by medical staff in emergency departments

Reiko Tsunoda[1,2*], Yumi Dobashi[1], Masao Noda[1,3] and Hiroaki Fushiki[1,2]

Abstract

Background Reduction of spontaneous nystagmus by fixation, a characteristic feature of peripheral nystagmus, is important for differentiating between peripheral and central vestibular disorders. In the emergency room, Frenzel goggles are recommended to observe spontaneous nystagmus for the differential diagnosis of acute vestibular syndrome. We developed a portable loupe with a Fresnel lens to observe nystagmus. The loupe does not require power supply and can be used under ceiling lights. The aim of this study was to quantitatively and objectively compare the abilities of the loupe and conventional Frenzel goggles to observe spontaneous nystagmus and to verify that the loupe can detect peripheral nystagmus that cannot be observed with the naked eye.

Methods Visual impact susceptibility was compared between the loupe and Frenzel goggles using the slow-phase velocity of nystagmus induced by the caloric test in 15 participants. Subsequently, under lighting, the nystagmus observations under the naked eye condition and with the use of the loupe were compared. Furthermore, the visibility of nystagmus was evaluated from recorded videographic images.

Results In observations of nystagmus induced by the caloric test, the visual impact of the loupe was not inferior to that of Frenzel goggles. The mean slow-phase velocity of nystagmus recorded with the loupe was significantly higher than that observed with the naked eye. Nystagmus weakened under bright lighting could be recovered by the loupe as fixation was blocked and the direction of the nystagmus could be defined.

Conclusions The results showed that the loupe is helpful in observing nystagmus, which is weakly observed with the naked eye under bright light. This portable, low-cost loupe, which yields superior results, can serve as an alternative to conventional Frenzel goggles in emergency medical settings where rapid assessment is required.

Keywords Fresnel loupe, Frenzel goggles, Nystagmus, Slow-phase velocity, Visual impact susceptibility, Visual fixation, Acute vestibular syndrome, Test of skew, STANDING algorithm

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Background

Peripheral vestibular disorders are the most common cause of vertigo; however, at diagnosis, central disorders must be ruled out. The Head Impulse, Nystagmus, Test of Skew (HINTS) and the STANDING algorithm are well known bedside tests for differentiating between central and peripheral dizziness in patients with acute vestibular syndrome [1–3]. However, the accuracy of the results of the HINTS examination administered by emergency physicians is lower than that achieved by neurologists and otolaryngologists [4, 5]. A study investigating the training of emergency physicians in HINTS and the STANDING algorithm found that the test of skew was the easiest assessment, whereas the evaluation of nystagmus with the Frenzel goggles was the most challenging [3]. Kerber et al. reported that, in the emergency department, nystagmus evaluation was frequently performed in patients with acute dizziness but the effect of fixation removal was not mentioned [6]. The examiner must observe the features of peripheral nystagmus that increases with fixation removal [7]. If visual fixation is not removed, it is difficult or even impossible, to recognize that the patient has peripheral vestibular nystagmus [8]. Frenzel goggles, infrared video goggles, or video-oculography can reduce fixation, enhancing the observation of nystagmus. Although neurologists and otolaryngologists use infrared video goggles and video-oculography in the outpatient setting, these devices are expensive and lack portability. Frenzel goggles are sturdy, portable, and useful tool in the emergency room [8].

A portable loupe based on a Fresnel lens that reduces visual fixation and magnifies the eye has been developed. It does not require power supply, is performed under ceiling illumination, and can be easily used in any location, including emergency departments. During practice sessions to observe physiological nystagmus, we reported that students were able to count similar numbers of nystagmus with the loupe as with the conventional Frenzel [9]. However, it is not the most suitable method for assessing nystagmus intensity. Rapid assessment is required during the clinical practice of emergency medicine. We believe that this loupe, which is highly portable, is more practical than conventional ocular observation devices. In this study, we performed a quantitative evaluation to clearly demonstrate the effectiveness of this loupe.

Methods

The slow-phase velocity (SPV) of nystagmus is the most useful measurement variable for quantifying the intensity of nystagmus [10]. The SPV of nystagmus induced by the caloric test was measured from electronystagmography (ENG) recordings. The visual impact susceptibilities (VIS) of the loupe and Frenzel goggles were calculated from the SPV and subsequently compared. Additionally, the utility of the loupe for observing nystagmus that is inhibited by the naked eye under bright conditions was investigated.

The loupe comprised a thin Fresnel plastic lens and storage cover (Fig. 1a, b). When the lens is placed in front of one eye and the other eye is closed using the storage cover, the observer can visualize the participant's eye magnified through the Fresnel lens; however, the participant's vision remains suppressed. The focal length of the loupe is 50 mm, and the magnification is 2x. The loupe is 10-mm thick with the lens and weighs only 24 g, making it portable [9]. Its storage size is appropriate for covering one eye in the test of skew (Fig. 1c). The loupe is used in normally illuminated areas, such as examination rooms and wards with ceiling lights.

Fifteen healthy participants with no history of visual impairment or dizziness were enrolled. Written informed consent was obtained from all participants after providing a written explanation of the purpose and methods of the study. This study was approved by the Medical Research Ethics Committee of Mejiro University (Approval number: 23 medicine-006). All procedures were performed in accordance with the tenets of the Declaration of Helsinki and its later amendments.

Nystagmus was induced by the caloric test and recorded using ENG (Daiichi Medical Co. Ltd., FNG-1004, Japan). The caloric test stimulus was cold air at 10 °C at a rate of 6 L/min (Daiichi Medical Co. Ltd., FAC-700, Japan). Cold air was injected into the ear canal for 60 s. All procedures are similar to the routine caloric test performed at our institute.

In our clinical practice, the caloric and the visual suppression tests [11] are performed consecutively to examine lateral semicircular canal function and cerebellar function. Lateral semicircular canal function is assessed using the maximum SPV of the caloric test in darkness, which reaches its maximum value approximately 30 s after the end of the stimulus. Therefore, the visual suppression test is performed 30 s after the end of the stimulus by instructing the patient to gaze at the target point for 15 s in a bright condition. The SPV during the visual suppression test in normal subjects is less than half the maximum SPV. After the visual suppression test, nystagmus recovers with darkness, but gradually decays spontaneously about 60 s after the end of the stimulus. Based on the above our clinical experience, the active phase of caloric nystagmus was defined as the period from the end of the stimulus to 45 s, and the decay phase was defined as the period after 60 s from the end of the stimulus in this study. The first 30 s of the active phase was conducted in complete darkness, and subsequently, the eyes were covered with a tool, i.e., Frenzel goggles or the loupe. When using Frenzel googles, the room remained

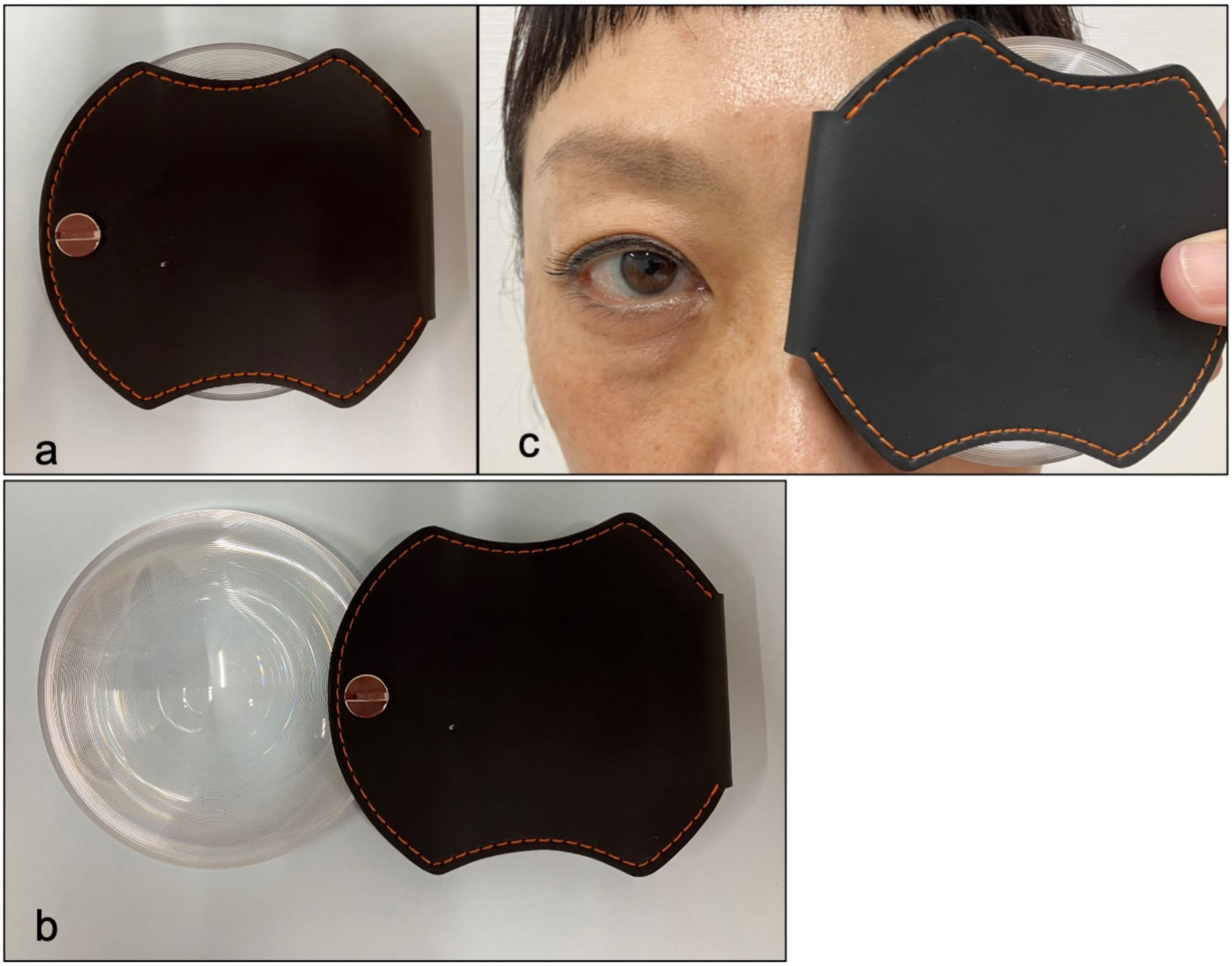

Fig. 1 Portable loupe based on the Fresnel lens. (**a**) The size of the loupe when the lens is in the storage cover is 90 × 90 × 10 mm. (**b**) The dimensions of the loupe when in use are 160 × 90 × 10 mm. (**c**) Its storage size is appropriate for covering one eye in the test of skew

darkened, and the lights inside the goggles were turned on (Fig. 2a). When using the loupe, the right eye was covered with a Fresnel lens, and the left eye with a storage cover, with the ceiling-light on (Fig. 2b). Each participant underwent caloric test for both ears. Different devices were used on the participant's left and right ears, and the order was randomized. During the decay phase, the ceiling light was turned on, and the participant's eyes were uncovered to achieve the naked eye condition for the first 15 s. Subsequently, the loupe was used as mentioned above.

Using ENG recordings, we measured the average SPV (°/s) over a 5-s period under different conditions and expressed it as mean SPV. The mean SPV in complete darkness was measured during the 25–30 s in the active phase. The mean SPV when using the loupe or Frenzel goggles during the activity phase was measured for 5–10 s after the change of conditions, because blinking increased and eye position fluctuated (Fig. 3).

When the loupe or Frenzel goggles are used, nystagmus is weaker than in complete darkness due to visual impact. To assess the visual impact of the tools, the ratio of mean SPV when using the tools to mean SPV in complete darkness was calculated for each ear as visual impact susceptibility (VIS) using the following formulas:

VIS of Loupe (%) = (mean SPV of the loupe) / (mean SPV of complete darkness immediately before) × 100.

VIS of Frenzel (%) = (mean SPV of Frenzel goggles) / (mean SPV of complete darkness immediately before) × 100.

The larger the VIS, the easier the observation of spontaneous nystagmus because visual fixation is reduced.

During the decay phase, the intensities of nystagmus in the naked eye condition and using the loupe were compared with the mean SPV for 5–10 s after the change of conditions (Fig. 4).

Data with a mean SPV of ˂10 °/s under complete darkness were excluded.

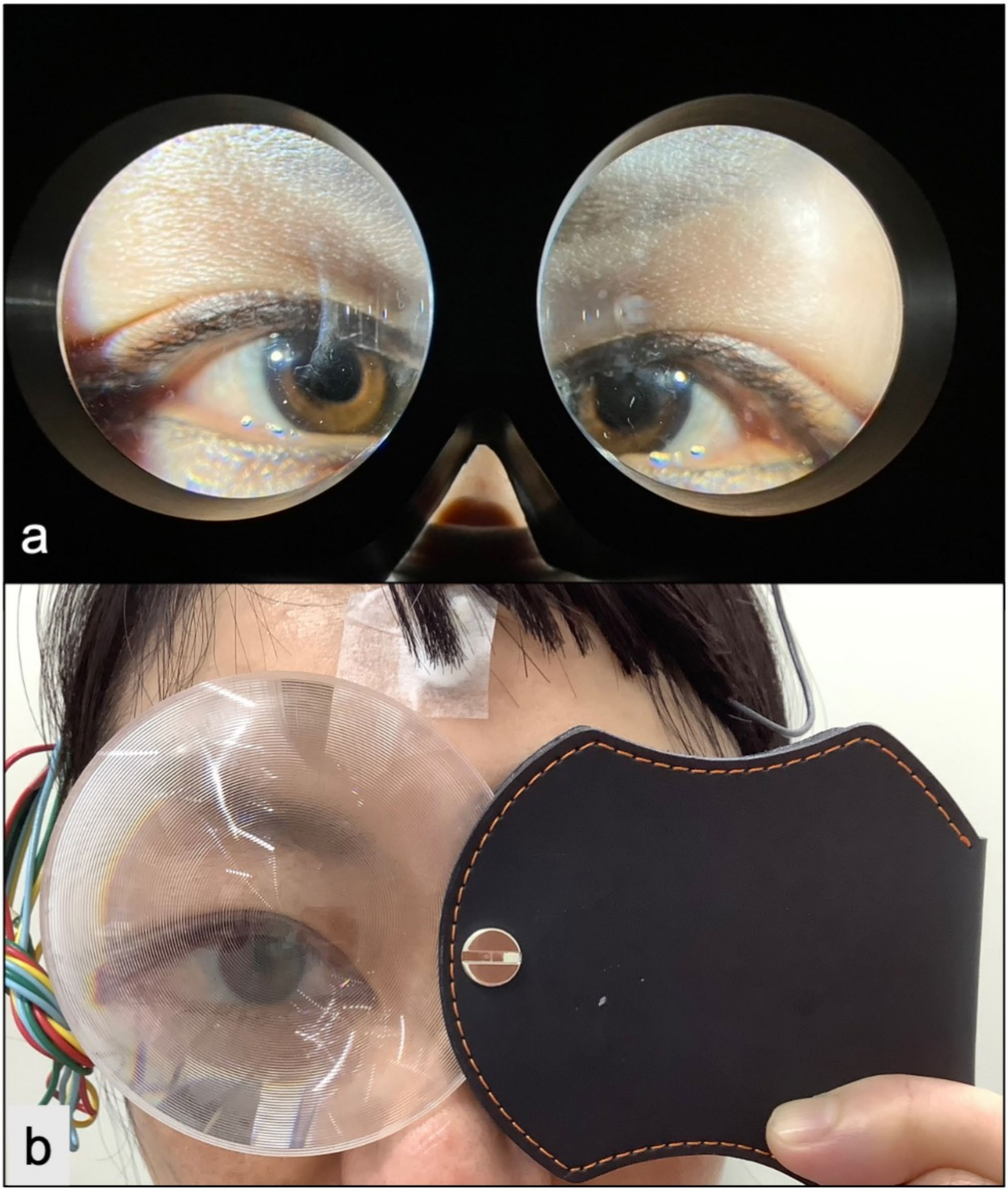

Fig. 2 Participants' eyes when using the nystagmus observation tools. (**a**) When using Frenzel goggles, the room remains darkened, and the lights inside the goggles are turned on. (**b**) When using the loupe, the ceiling light is turned on, the right eye is covered by the lens and the left eye is covered with the storage cover

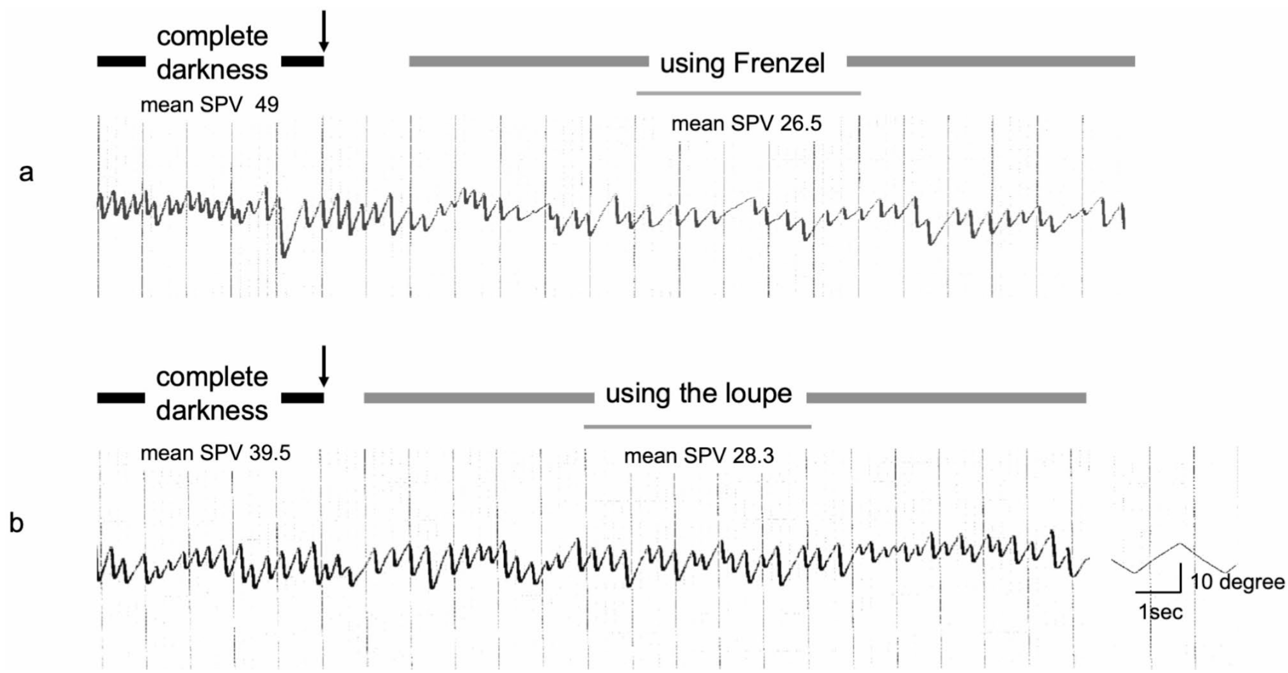

Fig. 3 Electronystagmography during the active phase of caloric nystagmus. Black arrow, 30 s after the end of the stimulus. In the complete darkness condition, the mean slow-phase velocity (SPV) of nystagmus was measured 25–30 s after the end of the stimulus. (**a**) For the Frenzel goggles (Frenzel), the mean SPV was measured 5–10 s after applying the Frenzel goggles. (**b**) For the loupe, mean SPV was measured 5–10 s after applying the loupe

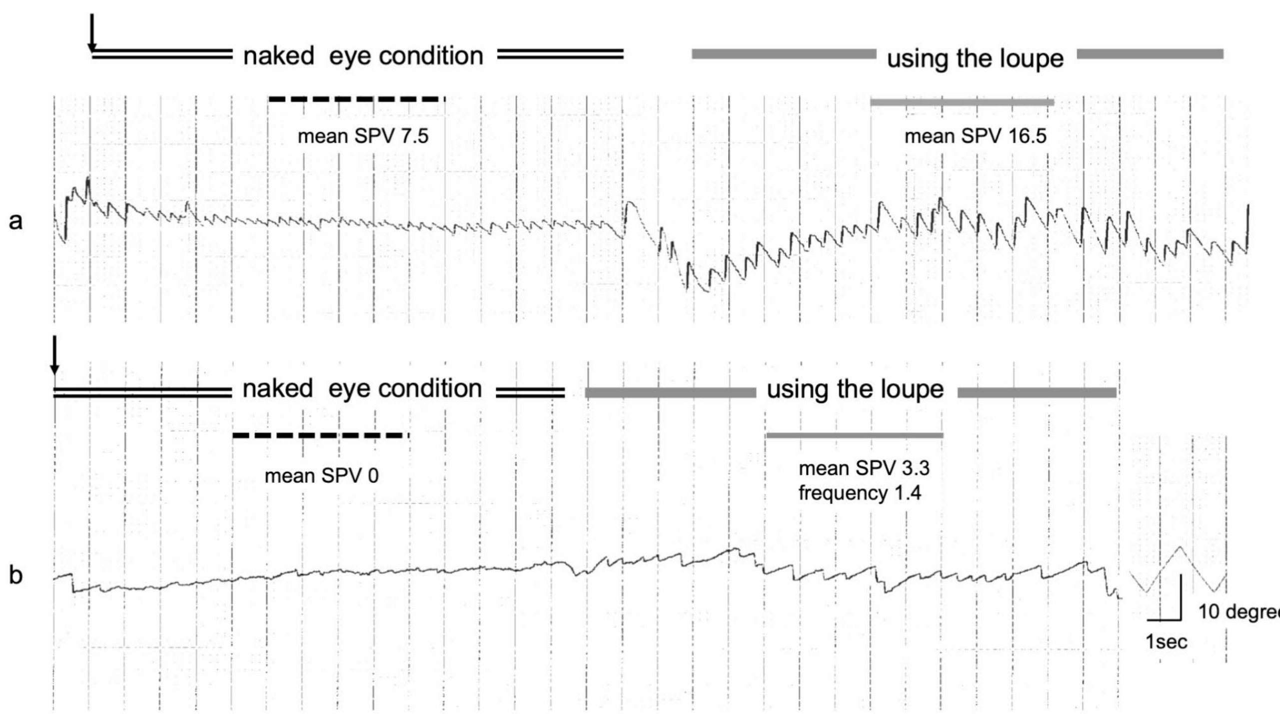

Fig. 4 Electronystagmography during the decay phase of caloric nystagmus. Black arrow, 60 s after the end of the stimulus. The ceiling light was kept on and recording was performed in the naked eye condition for 15 s, followed by recording during the use of the loupe. (**a**) The mean slow-phase velocity (SPV) with the use of the loupe is greater than that of the naked eye condition. (**b**) No nystagmus was recorded with the naked eye condition; however, nystagmus reappeared when using the loupe

Table 1 Mean SPV and VIS of the loupe vs. the Frenzel

Tool	Ears	Mean SPV of complete darkness mean (SD)	Mean SPV of using tool mean (SD)	VIS mean (SD)	Mean difference in VIS (95% CI)
Loupe	14	39.8 (17.9)	22.3 (9.6)	57.4 (14.0)	13.0
Frenzel	13	34.6 (15.6)	13.2 (4.8)	44.4 (19.6)	(−0.7, 26.7)

Data are presented as the mean (standard deviation) and mean difference in VIS (95% confidence interval)

SPV, slow-phase velocity (deg/s); SD, standard deviation; Frenzel, Frenzel goggles; VIS, visual impact susceptibility; mean difference in VIS, mean difference in VIS between the loupe and Frenzel; 95%CI, 95% confidence interval

Table 2 Mean SPV during the decay phase

	Ears	Mean SPV Median (25th, 75th percentile)	*p*-value
Naked eye condition	27	3.0 (0.0, 5.0)	
Loupe	27	5.0 (3.0, 7.3)	$p=0.000$

Data are presented as median (25th percentile, 75th percentile)

SPV, slow-phase velocity (°/s)

Table 3 Score derived from the videos during the decay phase

	n	Score Median (25th, 75th percentile)	*p*-value
Naked eye	8	10.5 (4.3, 11.8)	
Loupe	8	12.0 (11.3, 12.0)	$p=0.013$

Data are presented as n, median (25th percentile, 75th percentile)

Concomitant with the ENG recording, nystagmus was recorded on video with a camera fixed 50 cm in front of the eyes in eight participants. In the active phase, eight videos were evaluated for the loupe and Frenzel goggles each. In the decay phase, eight videos were evaluated, because one side of the participants was randomly selected. Six clinical staff members who were well-trained in nystagmus observation (two nurses, two laboratory technicians, and two physical therapists) independently assessed nystagmus visibility in the video files. Each staff members gave a rating score from 0 to 2 points: Clearly visible nystagmus direction: 2 points, unclear direction: 1 point, no nystagmus: 0 point. The sum of the scores by the six staff members was used as the score for each video (0–12 points).

The Shapiro–Wilk test was used to determine whether the data were normally distributed. If the *p*-value of the Shapiro–Wilk test was ≥0.05, the data were considered to follow a normal distribution and parametric tests were applied. Conversely, if $p<0.05$, the data were considered to deviate from normality and a non-parametric test was employed.

The main outcome was the VIS of Loupe compared with VIS of Frenzel; the 95% confidence interval (CI) for the mean difference in VIS between the loupe and Frenzel was calculated. As a secondary outcome, the mean SPV under the naked eye was compared with the mean SPV when using a loupe during the decay phase using a paired t-test or the Wilcoxon signed rank test (one-sided). Finally, for each video, the scores of the naked eye and loupe assessments in the decay phase were compared using the Wilcoxon signed-rank test (one-sided). The *p*-value<0.05 was considered significant (Bell Curve for Excel Ver. 3).

Results

One participant had a bilateral mean SPV of ˂10 °/s in complete darkness, and one participant refused second test owing to discomfort from dizziness induced by the caloric test. Therefore, the VIS of the loupe for 14 ears and VIS of the Frenzel for 13 ears were obtained. In the decay phase, data for 27 ears (14 individuals, 2 men; median age, 19 years; range, 18–37 years) were obtained.

Mean SPV values under each condition during the active phase and VIS for each tool were found to be normally distributed. The respective mean SPVs of the loupes and Frenzel were smaller than that under complete darkness (Fig. 3). The VIS of the loupe was 57.4±14.0%, and that of the Frenzel was 44.4±19.6%. The mean difference in VIS between the loupe and Frenzel was 13.0% (95% CI=−0.7–26.7%, $p=0.063$). The VIS of the loupe was not inferior to that of Frenzel goggles (Table 1).

In the decay phase, the mean SPV in both conditions were determined to deviate from normality and a Wilcoxon signed-rank test was performed. The mean SPV using the loupe was significantly greater than that of the naked eye condition (5.0 vs. 3.0 °/s, $p=0.000$; Table 2).

Although nystagmus was not observed in seven ears under the naked eye condition, it reappeared in six ears when using the loupe (Fig. 4b).

All videos with the loupe and Frenzel goggles during the active phase were assessed accurately and clearly in the direction of the nystagmus, i.e., all videos had a score of 12. During the decay phase, the median video scores were significantly higher scores for the loupe at 12.0 points than those for the naked eye condition at 10.5 points ($p=0.013$; Table 3).

Discussion

Strupp et al. developed binocular Fresnel lenses as an alternative tool to Frenzel goggles [12]. The performance of the loupe in this study was assessed using a method similar to that used by Strupp et al., i.e., quantitative evaluation of the SPV to clarify the usefulness of the loupe in a clinical setting. The mean SPV in complete darkness in this study is equal to the maximal SPV of caloric nystagmus, which is used to assess lateral semicircular canal function. The mean SPV of the loupe and Frenzel goggles immediately after reaching the maximum SPV decreased due to the visual impact rather than natural decay. This is because the ceiling lights are turned on when using the loupe, and when using Frenzel goggles, the room is dark but the lights inside the goggles are turned on. We were the first to introduce VIS to assess the visual impact of the tools in this study, based on the method of the visual suppression test [11]. VIS, which was described as the ratio of the mean SPV during the use of the nystagmus observation tool to the maximum SPV, was considered appropriate for assessing the impact of vision.

Furthermore, nystagmus, which was weakened in the naked eye condition under ceiling light during the decay phase, recovered (as evidenced by the mean SPV) when the loupe was used. Moreover, in six ears, nystagmus that had disappeared under the naked eye condition reappeared with the use of the loupe and could be recorded by the ENG. Our results indicate that nystagmus that is not visible in the naked eye condition may be detectable with the loupe in the clinical setting. Newman-Toker et al. reported the penlight cover test and stated that it was useful in patients with minimal or no nystagmus under conditions of fixation [13]. The loupe also allows clinicians to observe nystagmus, which could not be seen with fixation and requires no special technique.

Other methods are reportedly useful in observing peripheral nystagmus at the bedside. Umapathi demonstrated that nystagmus can be manifested by high dioptric glasses or thin eyelid coverings, i.e., closing the eyes, in patients with vestibular neuritis [14]. Eye movements can also be recorded using a pair of glasses with 20x lenses and a smartphone [15]. Although these methods are effective, the results depend on the skill of the examiner and the intensity of nystagmus that can be observed with these tests has not been validated.

It is recommended that Frenzel goggles should be used in a dark room with the goggles' built-in light bulb turned on, and this protocol was followed in this study. However, darkened rooms can be dangerous depending on the patient's state of health and mind. In such instances, it can be substituted by the loupe in a ceiling-lit room, which is better from the utility and patient safety perspective.

The limitations of this study include the fact that it was performed in participants with non-physiologic nystagmus induced by the caloric test. To clarify the utility of the loupe in clinical settings, further studies in patients with peripheral nystagmus, such as vestibular neuritis, are needed. In addition, the intensity of vestibular nystagmus induced by caloric stimulus may vary even in the same person. Therefore, it is also a limitation of this study that the caloric stimulus is not suitable for assessing deviations between the test and re-test.

Conclusions

The portable loupe can serve as an alternative to the conventional Frenzel goggles. Moreover, the loupe does not require a power source and allows for nystagmus observation in the examination room under ceiling illumination. In emergency clinical practice, this loupe can easily remove visual fixation and is useful for determining spontaneous nystagmus enhancement, which is a feature of peripheral nystagmus. It is particularly useful for detecting the presence of peripheral nystagmus, which is usually visually suppressed, in the absence of nystagmus upon naked eye examination of the dizzy patient.

Abbreviations

ENG	Electronystagmography
HINTS	Head Impulse, Nystagmus, Test of Skew
SPV	Slow-phase velocity
VIS	Visual impact susceptibility

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Author contributions

The Fresnel-based loupe was designed by HF. Data collection was performed by RT and YD. Data analysis was performed and the first draft of this manuscript was written by RT. DY, MN and HF critically reviewed the manuscript. All authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This study was approved by the Medical Research Ethics Committee of Mejiro University (Approval number: 23 medicine-006). Participants were informed regarding the purpose and methods of the study in writing, and written informed consent for participation was obtained. All methods were conducted in accordance with the relevant guidelines and regulations.

Consent for publication

Written informed consent was obtained from the participants for publishing the data. Written informed consent was obtained from all participants for the publication of identifying information/images in this online open-access publication.

Competing interests

The authors declare no competing interests.

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