# Beam-deflection method of diagnosing impaired vision

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**ABSTRACT**

We describe a simple method to assign a diagnosis of cataract to patients with obscurely impaired vision as well as to those with mild lens opacities. When the narrowest slit is used in a slitlamp examination, a small beam of light appears on the macula. Routine fundoscopy with the 78.0 diopter lens or a 3-mirror glass is appropriate. If a cataract is present, the beam of light is scattered into several straight lines, distorted lines, or both. This has proved a useful diagnostic tool when the lens appears clear but the patient's vision is impaired, and extensive examinations such as computer tomography or nuclear magnetic resonance tomography for impaired vision may be avoided. The beam-deflection method uses devices that are generally available and can detect cataract in the early stages of development. *J Cataract Refract Surg 2001; 27:994–999 © 2001 ASCRS and ESCRS*

In cases of mild cataract with faint lens opacities, it may be difficult to find the cause of obscurely impaired vision. The ophthalmologist may fail to recognize zones of increased light scattering in the nuclear region of the crystalline lens when brunescence is not present. Thus, unremarkable morphology of the eye compartments calls for intensive evaluation including perimetry, electrophysiology, and neuroradiology. These examinations may be avoided by using a simple method we developed to clarify the diagnosis of impaired vision caused by cataract. This beam-deflection approach complements the classic methods of investigation, which typically consist of slitlamp examination with lateral light, Scheimpflug imaging,[1] and laser scattering.[2]

During fundus examinations with the 3-mirror glass, we observed that the slitlamp's beam was deformed by lens opacities. This phenomenon was only visible at the appropriate slitlamp setting; that is, coaxial light, slightly defocused. This article describes our technique to evaluate vision impaired by cataract, its clinical application, and the optical explanation of the beam-deflection phenomenon.

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## Technique

*Examination*

The slitlamp's illumination beam is aligned coaxially with the microscope's viewing axis. The height of the slit is limited by the pupillary aperture, and its width is set as narrow as possible. For the adjustment, the slit is totally closed at first and then slightly reopened.

The slit is focused on the macula to arrange the slitlamp, the patient, and the mirror glass in proper position. A 3-mirror glass or a 78 diopter magnifying lens is used. To produce the beam-deflection phenomenon,


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the slitlamp is moved back about 5.0 mm toward the examiner and the slit slightly defocused again.

With a clear lens, the slit image is fuzzy and becomes broader after defocusing. If there are lens opacities, the light beam shows dark areas and seems to split (Figure 1). The beam's image may show double or multiple dark areas. Distortions and twisting of the beam may also be observed.

The entire examination mimics a fundoscopy. However, the goal is not to look for retinal changes but rather to make visible the optical phenomenon. As the fundus is examined, image changes are observed that have their origin in light pathway modulations caused by the affected lens. Although it may feel odd using a defocused slitlamp with an extremely narrow slit, it is more easy to search for the effects shown in Figure 1 once the examiner becomes familiar with the technique. Retinal changes (macular holes, edema, cysts, pucker, wrinkles) do not exhibit patterns such as those mentioned here because they appear only in a well-focused image formed in the retinal plane.

For a thorough examination, the slitlamp is scanned over the entire width of the pupil. With lateral motions of a vertical slit, the standard slitlamp control stick operates as usual. However, the examination works in any direction and with any orientation of the slit. The beam-deflection phenomenon occurs when the slitlamp beam passes a pathological part of the crystalline lens. Therefore, it may not always be visible to the observer while watching the beam projection to the fundus. The entire pupil (ie, the crystalline lens) is scanned with the light beam. This step is important because the appearance of the retinal image of the defocused slit changes with this positioning and image alterations may appear only at certain locations. During the slitlamp's motions, the appearances become more obvious because of sudden changes in the image projected on the retina. In addition, any change in appearance becomes more apparent when moving.

*In Vitro Model*

An in vitro model for cataract was created to better elucidate the beam-deflection phenomenon. An in vitro representation of vacuoles was used for 2 reasons: (1) In the beginning of cataract formation, water is sedimented because of a disproportion between the stroma and hydration. This creates vacuoles.[3] (2) The beam-deflection technique is mainly used to examine early cataract.

To prepare the model, a macro disposable cuvette (1.0 cm $\times$ 1.0 cm $\times$ 4.5 cm) was filled with gold-leaf-gelatin (Vaseline Factory Rhenania), which was melted. Just before the gelatin resolidified, liquid paraffin was injected, forming small drops that created vacuoles with different refractive indices (Figures 2,*A*,*B*). As the cuvette was brought into the optical pathway of a slitlamp, adjusted to the setting outlined above, the beam-deflection phenomenon was reproduced qualitatively (Figure 2,*C*).

To examine the optical pathway in a lens with vacuoles, a computer simulation corresponding to the in vitro model was performed using a ray-tracing program.[4–6] The simulation was based on the assumption

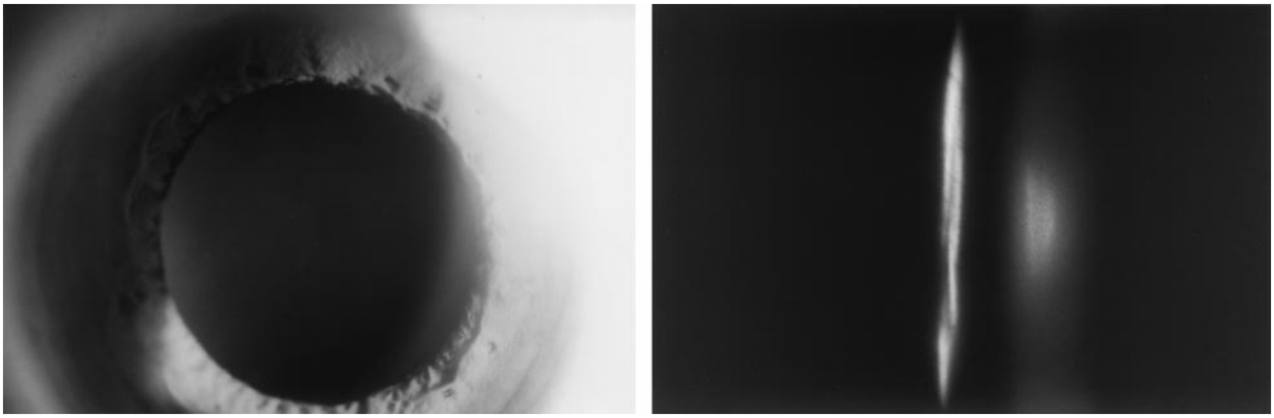

**Figure 1.** (Frohn) *Left*: Light lens opacities in a 62-year-old man with impaired visual acuity (20/40). Several evaluations were performed including perimetry, electrophysiology, and nuclear magnetic resonance imaging; all resulted in normal findings. *Right*: The slitlamp's light beam was deformed as a result of the patient's optically significant cataract. After this observation, cataract extraction was scheduled. Three weeks postoperatively, BCVA was 20/20.

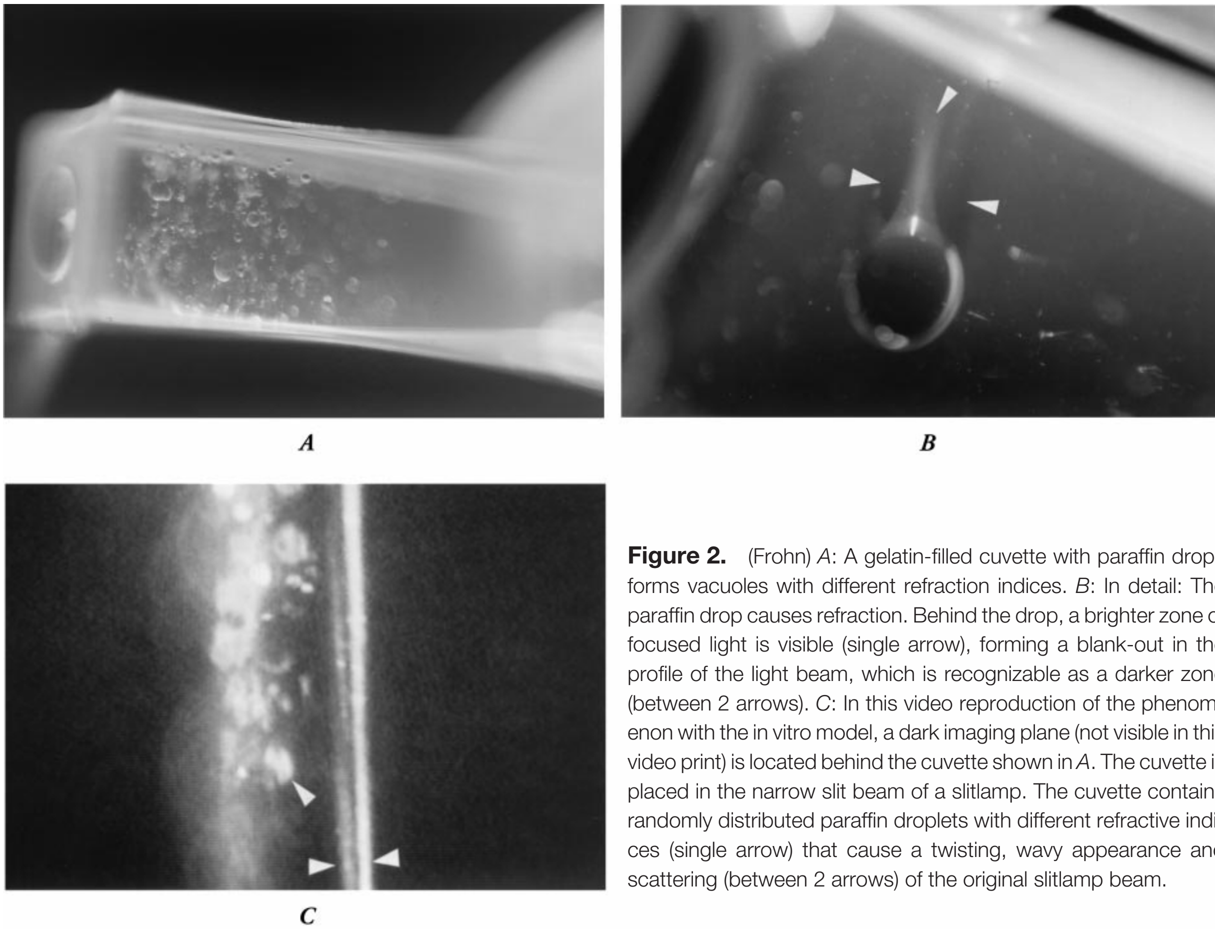

**Figure 2.** (Frohn) *A*: A gelatin-filled cuvette with paraffin drops forms vacuoles with different refraction indices. *B*: In detail: The paraffin drop causes refraction. Behind the drop, a brighter zone of focused light is visible (single arrow), forming a blank-out in the profile of the light beam, which is recognizable as a darker zone (between 2 arrows). *C*: In this video reproduction of the phenomenon with the in vitro model, a dark imaging plane (not visible in this video print) is located behind the cuvette shown in *A*. The cuvette is placed in the narrow slit beam of a slitlamp. The cuvette contains randomly distributed paraffin droplets with different refractive indices (single arrow) that cause a twisting, wavy appearance and scattering (between 2 arrows) of the original slitlamp beam.

that in a cuvette, randomly distributed vacuoles of different sizes are present. Ray tracing was used to calculate the pathway of a bundle of parallel rays, representing the beam of a slitlamp, through the crystalline lens (or a cuvette), taking Snell's law into account. This demonstrated the numerous refractive and total reflection processes that cause selective deflection of parts of the original light bundle (Figure 3).

## Results

Figure 3 shows the mathematical background of the optical process in the stroma of an opacified crystalline lens. When a light beam hits a vacuole, refraction or total reflection occurs. With a clear lens and slightly defocused beam, a broadened image of the original slit emerges (Figure 4,*A*). At the vacuoles, or more generally at zones with a different refractive index around the lens opacities, parts of the light bundle are deflected. This light is now missing in the profile of the original beam (Figure 4,*B*). This result, derived from a theoretical computer simulation, is also experimentally shown in Figure 2,*B*, in which the parallel light bundle passes the droplet. The droplet causes refraction, and the light is focused behind the droplet. There is no focused light in the original bundle. Therefore, darker zones emerge in the original bundle next to the bright and focused rays.

Two conclusions can be drawn. First, light intensity is reduced around the focal plane of the slitlamp when cataract is present. Because this is difficult to observe, it appears to be impractical for use in clinical examinations. Second, in a slightly defocused plane, the lack of the deflected light is noticeable as a pattern of dark stripes (Figure 4,*C*). Hence, in the defocused slitlamp adjustment, a homogeneous broadened shape of the light bundle appears and the parts deflected by the vacuoles appear as dark stripes. In addition, the deflected parts of the light bundle may appear beside the original image of the light beam. The mechanism of beam deflection caused by vacuoles explains the phenomenon.

Clinical use of this method requires data about specificity and sensitivity. During the examinations, 2 pa-

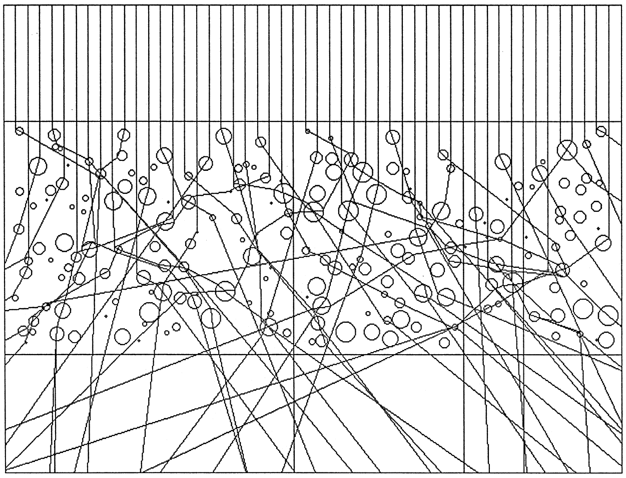

**Figure 3.** (Frohn) Ray-tracing simulation of a crystalline lens with drop-shaped inclusions of different refractive indices. *Upper*: A bundle of parallel rays, derived from the slitlamp. *Middle*: Rays in the crystalline lens (refraction and total reflection). *Lower*: Resulting profile of reflected or scattered light rays.

tient groups were formed. No patient had obvious corneal or retinal pathology. Both groups were examined with the same slitlamp (Zeiss SL160).

Group 1 consisted of patients with a best corrected visual acuity (BCVA) of 20/20 (Snellen chart) who were examined for reasons other than cataract. Of the 98 patients, 41 were men and 57, women. The mean age was 38.1 years ± 28.3 (SD). The youngest patient was 5 years old. All patients had a clear lens apparent at the slitlamp. The beam-deflection phenomenon was observed in 1 patient (1.03% false positive).

Group 2 consisted of cataract patients with known lens opacities screened for a fully functional macula and clear cornea. Patients had a BCVA worse than 20/20 but of 20/60 or better. The beam-deflection phenomenon might not be visible in cases with severe marked or mature cataract because of increased distortions of the light beam; therefore, patients with a visual acuity worse than 20/50 were excluded from this study. Of the 116 patients examined, 38 were men and 78, women. The mean age was 76.3 ± 12.2 years. The beam-deflection phenomenon was observed in 100 patients (13.8% false negative).

Although all patients in Group 1 had a clear lens and all in Group 2 were considered to have cataract, the groups were separated only by visual acuity to avoid bias by anticipating a diagnosis. Applying any cataract classification system would cause bias by the presumed diagnosis. Furthermore, as the beam-deflection technique should only be used to recognize early cataracts, the application of any accepted classification method would be useless.

Among all patients, sensitivity was 86.2% (95% confidence interval [CI], 78.6-91.9) and specificity was 98.9% (95% CI, 94.5-99.9).

The examiner was not blinded to visual acuity or the assumed amount of cataract. Eliminating these factors would have reduced bias but was unrealistic because to perform the method, the examiner had to use a slitlamp and could thus see the amount of cataract. Also, the examiner could see the patients and could be biased by estimating their age. A possible solution, taking photographs of the phenomenon, also produces bias because looking at photographs is not the original method. In addition, to achieve a statistically perfect analysis, all examined patients should have had surgery to prove that visual acuity reached 20/20 after removal of the crystalline lens. The latter is impossible from an ethical standpoint. Eventually, a degree of statistical imperfection had to be accepted for this study, but we do not believe this invalidates the findings and conclusions.

## Discussion

The beam-deflection method is a simple way to diagnosis cataract in some patients with obscurely impaired vision as well as in those with only mild lens opacities. Subtle variations in the refractive index within the crystalline lens, enough to cause a decrease in vision, are visible by this method. These irregularities may not be visible by a straight slitlamp examination. In a way, this method mimics the ideas of modern aberrometry[7] based on the knowledge of Tscherning.[8] Thus, thorough examinations such as perimetry, electrophysiology, nuclear magnetic resonance imaging, and computer tomography may be avoided to reduce the discomfort of and expense to patients. The advantages of the beam-deflection method do not free the examiner from the responsibility of judging the overall clinical picture, however.

Our method also provides additional information if a super-pinhole potential acuity meter (PAM)[9,10] or laser interferometry is not available or the results are in doubt.[10] Beam deflection gives a qualitative idea of how much refractive irregularity is present but cannot predict

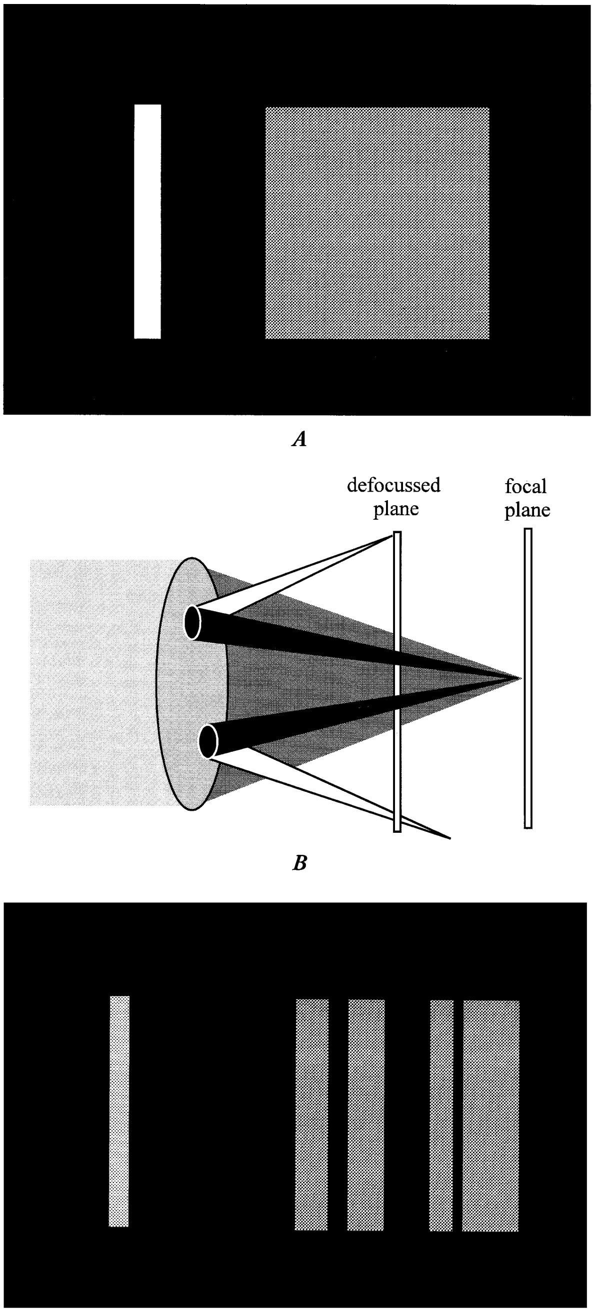


**Figure 4.** (Frohn) *A*: This example of the optical pathway in a clear crystalline lens shows a focused slitlamp image (schematic) on the left and a defocused slitlamp image on the right. The light beam is fuzzy and broadened. *B*: This example of an optical pathway with mild lens opacities and a subtle cataract after refraction and scattering of the light beam shows that parts of the beam are deflected and are, therefore, missing in the original beam profile. This reduces the light intensity around the focal plane. In defocused planes, the missing parts of the beam profile will appear as dark stripe patterns. *C*: The left portion of this schematic of a focused image of the light beam in an eye with cataract shows that the image differs from the image in an eye with a clear lens (*A*) only in light intensity. To the right, the defocused image shows dark stripe patterns.

how much visual acuity will improve if the cataract is removed. It is an objective test, however, allowing the examiner to directly observe the optical aberrations produced by an early cataract. Thus, it is different from interference-fringe instruments and the PAM, which can predict retinal visual acuity and are extremely useful in cases of less dense and nonobvious cataract.

The beam-deflection phenomenon is only visible in clinical application, when the beam of the slitlamp is slightly defocused on the retina. Only then are the deflected parts of the original beam visible as dark lines in, or as brighter lines next to, the original light beam. In a focused image, only a reduction in light intensity will occur, and it is difficult to perceive. Finally, motions of the slitlamp are essential because the phenomenon becomes more visible to the observer; in a still frame, the alterations may be subtle.

Our method is similar to the Shadowgraph test opticians use to examine pieces of optical glass for index-of-refraction inhomogeneities and inclusions. Both methods are founded on the same physical nature and are related to the subjective stigmatoscopy technique.[11] As outlined by von Helmholtz in his treatise on physiological optics, a point light source was used to project an out-of-focus image, with the shadow of every optical irregularity from the tear film to the posterior vitreous being carried to the direct observation of the patient. Instead of the point light, a slit-light source is used in our test, facilitating observation of alterations, which are more obvious in an altered point projection. The slit-light source allows the examiner to evaluate distinct areas of the lens, which is not possible when the entire pupil is passed at once by the defocused beam. Furthermore, alterations in projection are not observed or reported by patients, as in subjective stigmatoscopy, but rather by the examiner.

In general, the location of the image aberration on the fundus correlates with the region of the lens causing the aberration. Two limitations must be taken into account. First, it is important to scan across the pupil (ie, the crystalline lens) so that only the region of the macula is illuminated. At the equator of the human lens, even clear lenses, the image distorts to an extent that the light-beam image is always altered. Also, the examination should be performed with the light beam perpendicular to the lens to avoid the irregular optics encountered when viewing obliquely through the pupil. By this, the examination is limited to the central parts of the lens. This restriction is reasonable as only opacities that cause distortions around the macula can significantly impair vision.

The second limitation is the width of the slitlamp beam at the plane of the patient's pupil. Although the adjusted slit width is small and the slit is focused near the retinal plane, the beam has a minimum width at the pupil plane. The width of the beam (w) determines the spatial sensitivity (SpatS) of the method for locating the region of the lens causing the aberrations ($w \sim 1/SpatS$). This limits the beam-deflection method to qualitative rather than quantitative results because the width of the beam at the pupil depends on the proper adjustment to a very narrow slit and on the type or model of the slitlamp used. These limitations are not a problem when the method is applied during routine diagnostic examinations. However, the technique is not suitable for scientific classification of cataract as long as the properties of the used slitlamp are not taken into account.

We believe the beam-deflection method should not be applied when obvious corneal changes are present. Observations of keratoconus have shown that the beam-deflection phenomenon does not occur in such cases. However, not enough data are available to make a final judgment. The goal of our method is not to identify a cataract when recognizable morphological changes in other compartments of the eye are obvious (eg, corneal dystrophy, keratoconus, dense cataract). Rather, the observation of beam deflection provides an additional criterion for the morphological evaluation after other known changes have been biomicroscopically excluded.

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