Srinagarind Med J 1995; 10(1) 1-5

POTENTIALS AND LIMITS OF MODERN OPTICAL INSTRUMENTS FOR THE NON-INVASIVE INVESTIGATION OF THE ANTERIOR EYE SEGMENT

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บทคัดย่อ

การพัฒนา และการออกแบบเครื่องมือที่ใช้ในการตรวจวัดรูปร่าง ลักษณะ และคุณสมบัติทางสรีระของกระจกตา และเลนส์แก้วตา เจริญรุดหน้าไปมาก กล้องถ่ายภาพที่ผลิตขึ้นโดยอาศัยหลักการ ของ Scheimpflug (Topcon SL-45, Zeiss SLC, Oxford Case 2000, Nidek EAS 1000) สามารถใช้ตรวจวัดการแตกกระจายของแสงและขนาดทางชีวภาพในกระจกตา และเลนส์ตาได้อย่างละเอียดแม่นยำ นอกจากนี้ยังสามารถใช้ตรวจตำแหน่งของต้อกระจก ตลอดจนความขุ่นและการเปลี่ยนแปลงของต้อกระจก ซึ่งสามารถนำข้อมูลดังกล่าวไปใช้ในการศึกษาวิจัยเชิงทดลอง แบบมองไปข้างหน้าหรือข้อมูลทางระบาดวิทยาได้เป็นอย่างดี ปัจจุบันได้มีการประยุกต์นำแสงเลเซอร์และหลักการของการรวมแสง (confocal) มาใช้ในการตรวจวัดการแตกกระจายแสง (scattering), การเรืองแสง (fluorescence) และการดูดซับแสง (absorption) ภายในลูกตา ซึ่งเราสามารถนำเทคนิคดังกล่าวมาใช้ในการศึกษาขบวนการทางสรีระวิทยาของเนื้อเยื่อในลูกตา ตลอดจนการกระจายตัวของยาในลูกตา เป็นต้น

Abstract

Considerable progress has been made in the development and design of optical instruments that allow precise measurements of the morphological and also physiological properties of the transparent media of the eye namely the cornea and the lens. Cameras that are built according to the Scheimpflug principle (Topcon SL-45, Zeiss SLC, Oxford Case 2000, Nidex EAS 1000) allow precise measurements of light scattering and biometrical parameters of the cornea and the lens. Cataracts can be monitored with respect to their location, development and progress, so that also prospective experimental and epidemiological data are obtained. The technique of retroillumination, which is already implemented in the Case 2000 and the EAS 1000, can provide additional information but on its own did not prove to be reliable for clinical studies. At the moment, new diagnostic fields are opened with the application of laser light scattering combined with the confocal principle to the measurement of scattering, fluorescence and absorption in the eye. These techniques carry the potential to measure the dynamics of

physiological processes in the tissue as well as the distribution of drugs.

Key words : Scheimpflug principle, Retroillumination photography, laser ight scattering, confocal microscopy

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Introduction

The modern period of optical instrumentation in ophthalmology started at the beginning of this century with the invention of the ophthalmoscope by H. Von Helmholtz (1909), followed by the design of the first slitlamp microscope by A. Gullstran in 1911. These 2 instruments provided the possibility for detailed, non-invasive and direct investigation of all parts of the eye to the clinician as well as the scientist. Therefore it is not surprising that the first decades of this century were a period of tremendous progress in basic knowledge about the functions of the eye and the clinical management of various eye diseases. The introduction of scientific photography into ophtalmology due to the design of a fundus camera and the adaptation of camera bodies to the slitlamp microscope brought further progress with respect to documentation but did not provide new possibilities for direct optical measurement. This was most probably one of the reasons, why echographic techniques were introduced into ophthalmology, because they provided ways to determine refractive data as well as axial distances independent of the optical qualities of the eye. Due to the standardization of retroillumination photography and the introduction of the Scheimpflug principle into ophthalmology (Drews, 1964; Brown, 1969) transparency changes as well as alterations of the biometrical parameters of the transparent media of the anterior eye segment could be determined. Thus a basis for reliable data acquisition had been established for the performance of clinical as well as experimental studies to investigate factors that affect the transparency or optical function of the tissues of the anterior eye segment. It is the intention of this article to highlight the caracteristics of these techniques and to point out the potentials and promises of new measurement techniques in ophthalmology that are just being developed.

Instrumentation

SCHEIMPFLUG PHOTOGRAPHY has become an accepted technique in clinical and experimental studies in ophthalmology which is underlined by the fact that 4 different types of cameras have been constructed and commercialized during the past 12 years. They shall be briefly introduced here.

TOPCON SL-45-Topcon has commercialized the first Scheimpflug camera, named SL-45. It is a mechanical camera that is using a film (black-and-white or colour) as data storage medium. The camera body rotates mechanically (up to 180^0) around the optical axis of the light beam which coincides with the optical axis of the eye during photography. A xenon flash serves as light source during photography. Light from the same source also illuminates a bult-in grey scale, so that the origninal slit image of the anterior segment of the eye and an image of the 5 step grey scale are recorded simultaneously on the film (Hockwin et al, 1982; Hockwin et al., 1987). The image of the eye is recorded in its original size under a Scheimpflug angle of 45^0 . Additional information like the position of the camera and the study number or patient coding are also recorded on the same negative, so that this is a full data document. The camera has a variety of mechanical and opto-acoustical devices that allow precise and easy allignment of it to the patient's eye optical axis (Kampfer et al., 1989). The SL-45 is a mobile unit that can be easily transported to various locations. About 30 units of this camera are in operation in clinical and experimental ophthalmological centers worldwide.

ZEISS SLC- This system was the first video-operated Scheimpflug camera with integral image analysis. It consists of an elegant optics with rotating Nicole prisms so that there is no need for camera rotation. The Scheimpflug image is recorded by a video camera and is displayed immediately on a screen. If necessary, image analysis can be performed immediately on the digitized image or it is stored for later measurements. Light source as well as flash light of this camera is a regular halogen bulb, whose light emittance is electronically regulated and controlled (Wegener et al., 1987). The image analytical hard-and software of this instrument has been modified various times and today consists of a powerful computer unit with opto-magnetique storage media for large numbers of Scheimpflug images. The Zeiss SLC System is not designed to be mobile. 12 units of this system are in use world wide.

OXFORD CASE 2000 - This system in fact consists of 2 independent video cameras, a non-rotatable Scheimpflug camera with vertical slit position and a retroillumination camera. Both record their digital images on a magneto-optical disk. The images can be analysed with a modern software but due to its immobility, the versatility of this system is limited (Sparrow et al., 1990). The fixed Scheimpflug slit position does not allow any density measurement outside this position and the retroillumination image does not allow to quantify density changes in the lens, because any change in the refection quality of the fundus and even an image taken slightly off axis can change the background of an retroillumination image (Harris et al., 1991). The system is not designed to be mobile, about 5 units are in use worldwide.

NIDEK EAS 1000 - The system designed by Nidek reflects the most recent development in Scheimpflug photography. It combines the 2 techniques, Scheimpflug photography with a rotatable slit position (180^0) and retroillumination photography. The EAS 1000 has a unique optical alignment system, operated with infrared light. The patient is not disturbed by bright light and the investigator can align the eye with the aid of an electronique target (Sasaki et al., 1985) The video Scheimpflug image is recorded on a digital medium and can be either analysed directly or after storage of the whole series of images (Sasaki et al., 1990). The retroillumination image is recorded with the same optical system and can be used for area measurements (Sakamoto et al, 1990). As the whole system operation can be done with a portable computer, the system can be regarded as partially mobile. About 10 units are in use worldwide.

RETROILLUMINATION PHOTOGRAPHY as a technique to measure density changes in the transparent media of the eye has had only a limited acceptance up to now. Only one camera has been designed specifically for that technique, the :

NEITZ CTR - The camera uses black-and-white or colour film, the images are recorded together with a density scale that allows to compensate for changes in fundus reflection of the eye. Several fixation and alignment devices allow easy alignment to the axis of the eye (Kawara and Obazawa, 1980). Nevertheless, a variety of factors influences the reproducibility of retroillumination images recorded that cannot be always controlled (Chylack et al., 1987) About 6 units are in use worldwide.

Conclusion and Perspectives

The camera systems described above, especially those cameras based on the Scheimpflug principle, provide excellent tools for documentation and measurement of density changes in the cornea and the eye lens (Kojima et al., 1990). They are the instruments of choice for epidemiological studies in clinical cataract research (Chylack et al., 1983) as well as in basic research with animal cataract models. They provide precise data on transparency changes and changes in the biometrical parameters of the cornea and lens. Either film using or directly digitizing system today allow the handling of large numbers of images amd data, so that from this point of view there are no limits to the numbers of patients. They require, however, well trained personnel for operation of the camera, because the reproducibility of the image position depends largely on their ability to operate the system (Wegener et al., 1992) Also, the image analysis has to be done by experienced technicians because it will remain their responsibility to identify the corresponding peaks in the densitometric scan that are used for statistical analysis.

Besides these camera systems that are basically recording scattered light coming back from the eye, a new generation of instruments is under development : the CONFOCAL LASER SCANNERS. They are scanning the tissues of the anterior eye segment perpendicular to the Scheimpflug plane and their images are always real time video-recorded. Depending on their optical mode, either in liquid mediated contact with the cornea or in non-contact mode, they allow either high resolution images of the corneal cellular architecture alone, or the resolution of the image is lower but then their working distance is extended towards the posterior surface of the lens (Masters and Kino, 1990).

Besides the regular scatter image, the a daptation of various colours of laser light increases the information, that can be obtained with such a system from the living tissue in a non-invasive way, far beyond the actual limits. Location correlated fluorescence measurements for example could allow to monitor physiological reactions in the tissue, and even the presence of specific chemical compounds at a distinct tissue site could be determined (Masters, 1990). Within the next decade, this technique could open new horizons to non-invasive measurements in the transparent media of the anterior eye segment as well as in the posterior segment and the retina.

Parallel to the progress in the design of optical instruments for the analysis of the eye and its morphology also high resolution echography has become an important tool for non-invasive eye examination, but it would break the frame of this article to go into more detail here.

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