Slit Lamp - Some Aspects of Use in Clinical Examination

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Abstract
The relationship between the numerical aperture of the objective lens and the various aspects of the image formed in a slit lamp microscope like magnification and field of view, resolution and contrast, brightness, depth of field and stereopsis is described. The effect on quality of the image due to change in the magnification of the eyepiece, without changing the total magnification of the microscope is pointed out.

Keywords
Slit lamp, Bio-microscope, Numerical aperture, Eyepiece magnification.

Introduction
Slit lamp is essentially a microscope used in the examination of the eye. The aspects of a slit lamp of concern to ophthalmologists are magnification and field of view, resolution and contrast, brightness, depth of field and stereopsis in the image seen. This paper is an attempt to bring out the mutual relationship between these and also the optics of the instrument for best clinical examination.

Magnification and field of view
The magnification of the image in a modern slit lamp varies over the range of 5x to 50x. However the most commonly used magnifications for clinical examination are 10x, 12.5x or 16x. The magnification of the image is the product of the magnifications produced by the objective, the magnification changer, if any, and the eyepiece. The magnification is generally varied by changing the objective by flipping a lever or by setting the magnification changer at the desired value. It can also be achieved by changing the eyepieces. An increase in magnification always results in proportionate decrease in the field of view. It is possible to get the same total magnification with different combinations of eyepiece and objective magnifications. For example, a total magnification of 16x can be achieved with an eyepiece of 10x magnification and an objective of 1.6x or with a 16x eyepiece and a 1x objective or a 12.5x eyepiece and an objective magnification changer combination of effective magnification 1.28. Do all these combinations result in the same quality image? The purpose of this paper is to point out the differences in the quality of the image. To understand this let us look at other aspects of the slit lamp.

Resolution and contrast
If every point in the object gives rise to a corresponding point in the image as determined by geometrical optics, assuming that the lenses are free from all aberrations one would get a perfect image. However because of the wave nature of light and the diffraction effects, each point in the object gives rise to a small disc in the image. There is certain amount of overlap of these discs and some of the fine details and contrast in the object do not appear in the image. The smallest separation between details that are seen distinctly in the image is determined by the resolving power of the instrument. Larger the resolving power smaller is the spacing. For a microscope the resolving power is determined by the expression $0.61\lambda / NA$,[1] where λ is the wavelength of light and NA is the numerical aperture of the objective. It is approximately the ratio of the radius of the aperture of the objective to the distance of the object from the objective. The distance has to be greater than the focal length of the objective. When the NA increases the resolving power also increases.

The resolution is also limited by diffraction effect at the iris of the observer's eye. For a normal eye (undilated pupil) the separation between two points that are just resolved subtends an angle of one minute of arc at the eye.[2] When the finer details of the object, resolved in the microscope are to be resolved in the eye also, the image of the details magnified in the microscope should subtend an angle of one minute of arc. The necessary magnification has been worked out. It is 216NA.[3] For a typical slit lamp the NA is about 0.1 and the necessary magnification is about 20x. With a magnification less than this value the eye does not use the full resolution of the instrument. When the magnification is more than the necessary value the eye sets the limit and is not able to resolve the details resolved by the instrument. The magnification greater than 216 NA is termed empty magnification.[4]

The contrast (modulation) in colour or shade observed in the image is always different from what is present in the object. This is determined by a quantity known as modulation transfer function (MTF) of the instrument. The MTF is dependent on the spatial frequency in the modulation. If the spatial frequency is less (there are fewer variations over a given length) the MTF is close to unity and the modulation is seen fully in the image. If the spatial frequency is more, the modulation in the image becomes less. At a cut-off spatial frequency, the MTF is zero and no modulation (contrast) is seen in the image becomes less. It has been worked out that the cut-off frequency is determined by the diffracting aperture and it increases when NA increases.[5]

Brightness

This is determined by the amount of light entering the objective. Also when the magnification increases the brightness decreases. This is usually compensated by increasing the brightness of the bulb in the slit lamp. Since the area of the aperture is proportional to the square of the radius of the aperture, the brightness is proportional to the square of NA.

Depth of field

When the details in a plane in the object are in sharp focus as seen in the microscope, the details in the plane in front of and behind the given plane are also in reasonable focus; the separation between the latter planes is the depth of field. The depth of field has been worked out and it is inversely related to NA.[6] When NA increases the depth of field decreases and vice versa. For visual examination the depth of field is not much of consequence. Any plane can always be brought under sharp focus by moving the microscope forward or backward. For photographic work a good depth of field is needed and for this NA should be as low as possible. It is essential to remember here that a pinhole camera has infinite depth of field.

Stereopsis

This feature is very essential for clinicians. It has been shown that the stereopsis is good when the object is close to the microscope, the magnification is less and the separation between the objectives is as large as possible.[7] When NA is more, stereopsis is good. This cannot however be increased beyond certain value due to some other constraints.

Discussion

Let us return to the question - What is the effect of increasing the eyepiece magnification without changing the total magnification? When the eyepiece magnification increases the objective magnification decreases. For this to happen, without any change in the geometry of the microscope, the focal length of

Table 1: Summary total magnification same

Eye piece magnification	↓	↑
Objective magnification	↑	↓
Objective focal length	↓	↑
NA	↑	↓
Resolution	↑	↓
Contrast	↑	↓
Brightness	↑	↓
Streopsis	↑	↓
Depth of field	↓	↑

the objective has to be more. Because of the increase in focal length, the distance of the object is more. The NA is reduced. The consequences are decrease in resolution, decrease in cut-off frequency of MTF, decrease in brightness and decrease in stereopsis. The depth of field is increased and the working distance is more. In examination where greater working distance is needed a high power eyepiece is better, otherwise a low power eyepiece is always preferable. These are summarized in Table 1.

Acknowledgment

The author records his gratitude to Dr. G. Venakataswamy, Chairman, Aravind Eye Care System for the opportunity given to him to work at Aravind. The help and encouragement received from Dr. P. Namperumalsamy, Director, Aravind Eye Hospitals, Mr. R. D. Thulasiraj, Executive Director, Lions Aravind Institute of Community Ophthalmology and Dr. P. Balakrishnan, Engineering Director of the hospital are gratefully acknowledged.

Reference

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   2, 3, 4. Ibid 1, p 15.
5. Goodman J. W . *Introduction to Fourier Optics.* McGraw Hill (1968), p 120
6. *ibid 1, p 17*
7. *ibid 1, p 18*

** This paper was the keynote address at one of the sessions on optics in the 55th Annual conference of AIOS (All India Ophthalmological Society held at New Delhi in Feb, 1997)*

Maintenance tips

An old ophthalmoscope was brought for servicing. The reflecting mirror had fallen off. The user had lot of sentiments attached to his/her ophthalmoscope that he/she had used for years and wanted to continue using it. In principle one can write to the manufacturer for a reflecting mirror and fix it. If facilities exist one can also get vacuum deposition of aluminum on a small piece of glass and get it fixed in position. A simpler and a faster way, getting it done would be to go to a supplier of embroidery material and get some tiny reflectors that adorn the blouse and churidhars. They are made of glass or plastic. Plastic ones are better and will act like front silvered mirrors. It will be possible to select a good reflector from a sample of about 10 or 15 and use it as the reflector.

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