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NEW TELEOBJECTIVES FOR THE OPERATION MICROSCOPE AFTER BARRAQUER

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A description of the ZEISS Operation Microscope after Barraquer was given in a previous paper [1]. This instrument (shown in Fig. 1) has, in the meantime, proved its worth in practice. As it is well known, the instrument was designed with the intention of allowing the surgeon to adopt a comfortable sitting position similar to the one he has when operating with teleloupes. Fig. 2 shows to which extent this has been achieved. However, the advantage of the convenient sitting position could only be achieved by means of a compromise, namely by the elimination of the magnification changer inside the instrument.

However, even without the magnification changer, the magnification of the instrument can be varied within certain limits by exchanging objectives, tubes and eyepieces; but the magnifications thus achieved are in most cases too high. Magnifications below 8x to 10x are desired since these yield the advantages of larger depth of field and larger field of view. Furthermore, it is also very often desired to bridge the gap between the teleloupes (magnification in most cases only 1.8x) and the operation microscope.

A description follows of how this can be achieved with teleobjectives, specially computed for the operation microscope. Let us first deal with the relationships between the optical data of the individual elements of the microscope, the microscope magnification and the field of view. The design of the optical system of the microscope is such that there is a parallel path of rays between the main objective O_1 (cf. Fig. 3) with the focal length f_1, and the tube objective O_2 with the focal length f_2.

The object to which the microscope is adjusted thus lies on the lower focal plane of O_1 (Fig. 3 bottom), and is imaged into the upper focal plane of O_2

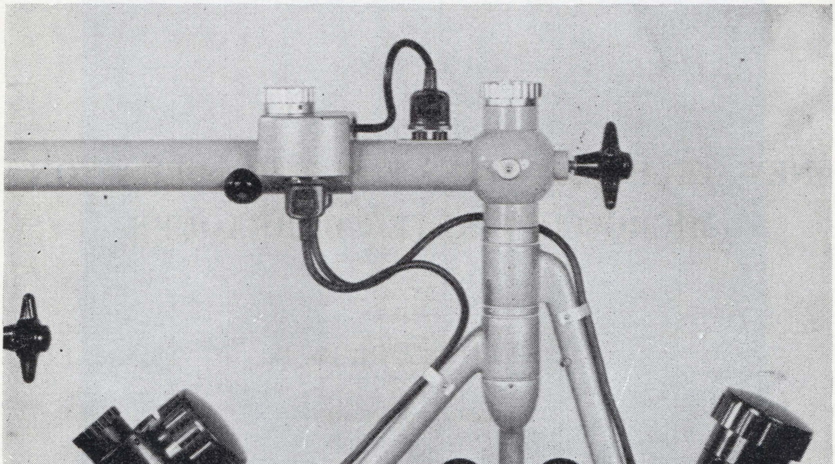

Fig. 1. ZEISS Operation Microscope after Barraquer

by means of the tube objective O_2. The magnification factor of this image is f_2/f_1. If the intermediate image thus produced in the tube is observed through an eyepiece O_3 of the eyepiece magnification V_3, then the total magnification of the microscope is

$$V = \frac{f_2}{f_1} \cdot V_3 \tag{1}$$

In this case the free working distance below the main objective O_1 is almost equal to its focal length f_1. According to (1) the microscope magnification could be reduced by increasing f_1 and thus the working distance. However, one of the principal advantages of this operation microscope being the small working distance, there is not sufficient freedom with regard to the selection of f_1. For this specific instrument $f_1 = 150$ mm.

There is no free choice with regard to f_2 either. According (1) the tube focal length f_2 should be as small as possible, if a low magnification is to be achieved. However, small tube focal lenght means small tube length. It is thus impossible to reduce the focal length to a value below 125 mm, since either the surgeon is then too near to the operation microscope, or the direct free view onto the operating field in the eye in unpermissibly impaired by the microscope body. In fact only two types of binocular tube were designed for the microscope concerned, a short tube of $f_2 = 125$ mm (on the right in Fig. 2), and a log tube of $f_2 = 160$ mm (on the left in Fig. 2). Practical experience has shown that, because of the superior freedom of view it offers, the long tube is more convenient that the short one.

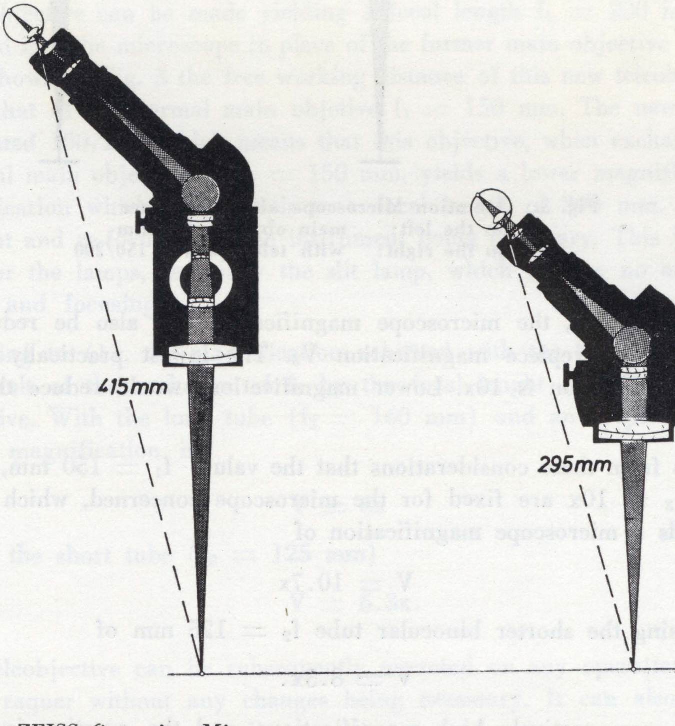

Fig. 2. ZEISS Operation Microscopes
on the left: Operation Microscope with magnification changer in 5 steps and a working distance of about 200 mm
on the right: Operation Microscope after Barraquer without magnification changer and with a working distance of about 150 mm

2. The focal length f_1 is increased, thereby maintaining the free working distance, i. e., O_1 is converted into a telesystem.

3. The focal length f_2 is reduced, thereby maintaining the tube length, i. e., O_2 is converted into an inverted telesystem.

The first solution means practically an extended microscope body similar to the original operation microscopes with Galileian changer, i. e., a solution which was intented to be avoided by the design of the operation microscope after Barraquer. The third solution requires considerable expenditure, since, owing to the image converting prism sets inside the binocular tubes, there is no space for an extended telelens. Furthermore, the tubes being binocular, these lenses would have to be made twice.

Compared with these two the second solution can more easily be realized.

A teleobjective can be made yielding a focal length $f_1 = 200$ mm, and can be inserted into the microscope in place of the former main objective of $f_1 = 150$ mm. As shown in Fig. 3 the free working distance of this new teleobjective is as large as that of the normal main objetive $f_1 = 150$ mm. The new teleobjetive is designated 150/200, which means that this objective, when exchanged against the normal main objective of $f_1 = 150$ mm, yields a lower magnification, i. e., a magnification which corresponds to a focal length of 200 mm, without any adjustment and re-focusing of the instrument being necessary. This is particularly true for the lamps, especially the slit lamp, which require no adjustment of direction and focusing.

According to (1), the magnification achieved with the teleobjective 150/200 is the result of the exchange of f_1 by the focal lenght $f_1 = 200$ mm of the teleobjective. With the long tube ($f_2 = 160$ mm) and an eyepiece $V_3 = 10x$ the total magnification is

$$V = 8x$$

and with the short tube ($f_2 = 125$ mm)

$$V = 6.3x.$$

This teleobjective can be subsequently mounted on any operation microscope after Barraquer without any changes being necessary. It can also be attached to the Film Microscope after Barraquer.

If the magnification is to be further reduced in a similar manner, another teleobjective (200/300) can be used. This can be exchanged against a main objective $f_1 = 200$ mm, without necessitating any re-adjustment of the microscope or the lamps. It then yields a magnification which corresponds to a focal length of $f_1 = 300$ mm. Both tubes then yield total magnifications of $V = 5.3x$ and $V = 4.2x$, if a 10x-eyepiece is used. These magnifications are in the immediate vicinity of the usual teleloupe magnifications. However, with regard to the latter objective it must be borne in mind that the arms, carrying the illuminators on the operation microscope are at present exactly focused and adjusted to $f_1 = 150$ mm. Thus, this objective can only be exchanged against a main objective $f_1 = 200$ mm if new adjustable lamp arms are mounted. Corresponding arms are under preparation and these can be exchanged against the present ones on any operation microscope after Barraquer. The teleobjective 200/300 cannot be used in connection with the film microscope.

By means of the main objectives $f_1 = 150$ mm and $f_1 = 200$ mm, and the two new teleobjectives 150/200 and 200/300 with corresponding tubes, and the eyepieces between 10x and 20x it is now possible to vary the magnification of the operation microscope concerned to a much wider extent than before. As can be gathered from the following table, the total magnification ranges from 4.2x to 21.4x.

MICROSCOPE MAGNIFICATIONS FOR DIFFERENT OBJECTIVES, TUBES, AND EYEPIECES

Objective	*Tube*	V_3 10*x*	12.5*x*	16*x*	20*x*
normal	short	8.3	10.4	13.3	16.6
150	long	10.7	13.4	17.1	21.4
tele	short	6.3	7.8	10.0	12.6
150/200 *	long	8.0	10.0	12.8	16.0
tele	short	4.2	5.2	6.7	8.4
200/300 **	long	5.3	6.7	8.5	10.6

* The normal main objective $f_1 = 200$ mm yields the same magnifications, but at a working distance of about 200 mm.

** The normal main objective $f_1 = 300$ mm yields the same magnifications, but at a working distance of about 300 mm.

The diameter of the field of view can be computed from the microscope magnification V according to the equation

$$\phi = \frac{200}{V} \text{ mm}$$

This simple equation is the result of a suitably related design of the eyepieces. At the magnifications indicated above, the field of view has a diameter of 10 to 48 mm.

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