Marcus-Matthias Gellrich

The Slit Lamp

Applications for Biomicroscopy and Videography

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Applications for Biomicroscopy and Videography

With a contribution by Dieter Schmidt
English translation by Carole Gustely Cürten

Springer

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This book is dedicated to my patients – both the grown ones and especially the little ones.

Foreword

The year 2011 was an important one in the history of ophthalmology: 100 years earlier, Allvar Gullstrand was awarded the Nobel Prize in Physiology/Medicine for his work on the "dioptrics of the eye." The same year, he introduced the slit lamp at the annual congress of the German Ophthalmological Society (DOG) in Heidelberg – the first time it was used as an instrument in ophthalmology. Gullstrand had developed the slit lamp together with the Carl Zeiss company in Jena. Since then, the slit lamp has been the ophthalmologists' most indispensable instrument – one that has been continuously improved and modified while maintaining its basic principle of operation.

Exactly 100 years later, Dr. Marcus-Matthias Gellrich published a book on the slit lamp in which he describes in detail and with contagious enthusiasm all of the practical applications that are possible with this marvelous piece of equipment. Inspiration for this effort was provided when Dr. Gellrich was awarded the Video Prize by the German Ophthalmological Society at their congress in 2007 for his film illustrating the enormous photographic potential of this so basic ophthalmological instrument.

What is particularly appealing to the reader is Dr. Gellrich's straightforward approach to what he refers to as "videography." This involves not just fundus findings documented using a handheld plus lens – the "short-sighted" slit lamp can also be outfitted with a minus lens and thus bring objects at greater distances into focus, such as eye muscle disorders or the patient's face. What a brilliant idea! It is great fun following his suggestions and learning about new examination techniques beyond the traditional investigative routine. Moreover, it is extremely useful. Marcus-M. Gellrich's *Slit Lamp* is a very worthwhile read for the eye doctor working in a clinic as well as the ophthalmologist with his or her own practice.

Professor Dr. med. Gerhard Lang
University Eye Clinic, Ulm, March 2011
President of the World Ophthalmology Congress in Berlin 2010

Preface to the German Edition

To help the reader to understand what motivated me to write this book – and its aim – I would like to pose a question that at first seems quite trivial, namely, where on earth is Kellinghusen?

There are two answers to that. The first: it's halfway between Hamburg and the Danish border. Here in the countryside between the North and Baltic Seas is my ophthalmological practice, where you will encounter the everyday routine of a country eye doctor.

The other answer: Kellinghusen is everywhere – in the USA, in England, Ukraine, or India – in all those places where ophthalmologists are practicing far away from a clinic or major city to serve their patients as best they can. Here in Kellinghusen and everywhere else, it is our duty to diagnose and treat diseases and when necessary, to monitor their course. To serve all of these functions well, we must be able to fully exploit the potential of the entire range of diagnostic equipment at our disposal.

The slit lamp microscope or as we know it, the slit lamp, is without a doubt the one piece of equipment we can least do without when examining our patients.

Although the exact date of its beginning is unknown, its year of birth is 1911, when Gullstrand first introduced it (Gellrich 2011a, b; Gullstrand 1911, 1912; Kroll et al. 2008). Much has happened since then: it has a new appearance and is much easier to handle, and its repertoire of applications has grown.

We can view not just the anterior eye and its sections but also, using supplementary optics, the fundus, iridocorneal angle, in fact, the entire eyeball!

In this book on the slit lamp, you will find a history of its construction, technology, and examination potential described in detail. I also present a new means of documenting findings – videography – with the slit lamp.

One hundred years after its invention, the investigative ophthalmological potential of its technology continues to grow.

The ophthalmologist usually consults his or her notes when monitoring a finding and evaluating its course. In most (straightforward) cases, our notes suffice. But when faced with more complex or chronic diseases, written documents make for a weak basis upon which to answer precisely "What has changed?"

Carrying out ophthalmological videography as described in this book, the ophthalmologist can successfully document all (!) of the eye diseases with the slit lamp and a video camera in a practicable, rapid, and affordable manner. A converging lens is used to view the posterior segment, and for portrait and strabismus images, diverging lenses, and to view the iridocorneal angle, a contact lens. At the end of that chapter, you will find 20 important videographic settings. What follows are "recipes" for applying these settings to the relevant chapters of ophthalmology; examples thereof are found on the DVD in the inside of the back cover, each with several clinical examples. This collection of clinical images is the world's first ever general atlas of ophthalmology from the perspective of the slit lamp.

It is my hope that through this introduction of ophthalmological videography – with its many images never before made with a slit lamp – I have provided both proof of this technique's value and inspiration to others to exploit it. I have been taking videographs with the slit lamp for years in my practice – in a manner of speaking, Kellinghusen could be anywhere!

Kellinghusen, Germany Marcus-Matthias Gellrich
February, 2011

Preface to the Extended English Edition

With the publication of this edition in English, a personal dream of mine has been realized. Whereas the major literature on the slit lamp was published in German in the early and mid-twentieth century, it must now be in English in order to reach a worldwide readership.

I am deeply grateful to Carole Cürten for her English translation of my book. She demonstrated dedication to and great enthusiasm for this daunting endeavor. Our frequent and detailed exchanges have been most rewarding, and I hope they will continue in the future.

I am particularly pleased that this book has been published by the Springer publishing house, as it was Springer who originally published the most important and still-formative early literature on the slit lamp, namely, the atlases of Alfred Vogt and Leonhard Köppe. My special thanks go to Dr. Sverre Klemp, to whom I was referred by my esteemed German publisher and mentor Dr. Reinhard Kaden. Dr. Klemp cleared the way for this English edition. His team around Mr. Srinath Raju, project manager in Chennai, accompanied its evolution most competently and sympathetically.

I also extend my gratitude to Dr. P. Balakrishnan and Professor V. Srinivasan from Aravind Eye Care System, Madurai, India, for having initially reviewed the English manuscript.

Professor Wagih Aclimandos, London, and Dr. Fraser Muirhead, California, provided helpful suggestions regarding English ophthalmological terminology.

In comparison with the original German edition (2011), this English edition has been updated with information and commentary on the practical experience I have gained over the previous two years. There are also two additional films so that the new concept of videography with the slit lamp is now thoroughly presented and incorporated in a film tetralogy. The DVD that accompanies this English edition should provide the reader with an entertaining overview of the slit lamp's potential.

Kellinghusen, Germany
October, 2013

Marcus-Matthias Gellrich

Acknowledgements

I would never have written this book were it not for a film that I submitted at the annual congress of the German Ophthalmological Society/Deutsche Ophthalmologische Gesellschaft (DOG) in 2007; that film accompanies this book. I extend my thanks to the DOG jury, especially Professor Dr. Gerhard Lang (Ulm) for honoring my film, entitled "The slit lamp overcomes its shortsightedness." That prize provided the decisive impetus for my further engagement with slit lamp videography.

Once I thought I had compiled enough material, I approached the publisher Reinhard Kaden at the DOG congress in 2009 with my ideas. Thus began an intimate exchange of ideas for which I am deeply grateful. This experienced publisher guided me, and the text has benefited from his many years as a practicing ophthalmologist, especially the chapter on the classic applications of the slit lamp.

I am also grateful to my former teacher Professor Dieter Schmidt (Freiburg) for not only writing the history chapter in this book so well but also for working his way through the atlas chapters.

Among my assistants in the practice, special thanks to Nathalie Bolz, who early on understood how to bring the image and text for the atlas into an attractive and readable format. Warm thanks also go to Christian Molter at the Kaden Verlag for so expertly designing the layout.

How easy it is sometimes to forget those who are closest to us, who give us so much support without us ever having to request it! I shared what little time I had left at the end of my work day (the practice was open as usual throughout the writing of this book) with my dear wife Imme and our two sons Finn and Lasse. Our boys have grown more than a few centimeters while I wasn't looking!

Marcus-Matthias Gellrich

Contents

1 Basics

1.1 Appliance Construction

1.1.1 Application Overview

The slit lamp (Fig. 1.1) is the most versatile and indispensable piece of equipment in the ophthalmologist's practice. We use it not only to view the eye's anterior segments including the lens and vitreous body. The iridocorneal angle and deeper segments of the eye can be viewed using contact and handheld lenses. Accessory attachments have been developed that make the slit lamp more than just an observational unit – it can also take measurements, including intraocular pressure, and play a key role in the fitting of contact lenses (Kroll et al. 2008).

By connecting it to a camera, findings can be photodocumented. Connected to a video camera, movement can be documented, i.e., nystagmus, pupil reactions, and gaze saccades (Gellrich 2011a).

1.1.2 General Slit Lamp Design

A slit lamp consists of three main parts (Fig. 1.2):

1. Its illumination unit (the slit-shaped beam it emits has given this appliance its name)
2. A stereomicroscope (in this form, the stereomicroscope is used in other ophthalmological appliances, such as the surgical microscope)
3. The appliance mechanics (the mechanical principle behind the slit lamp joins the microscope with the illumination unit, so that it can be positioned correctly to accommodate the patient)

Fig. 1.1 Slit lamp SL 105 by Carl Zeiss company – the instrument used throughout this book for almost all images

M.-M. Gellrich, *The Slit Lamp*, DOI 10.1007/978-3-642-39793-6_1,
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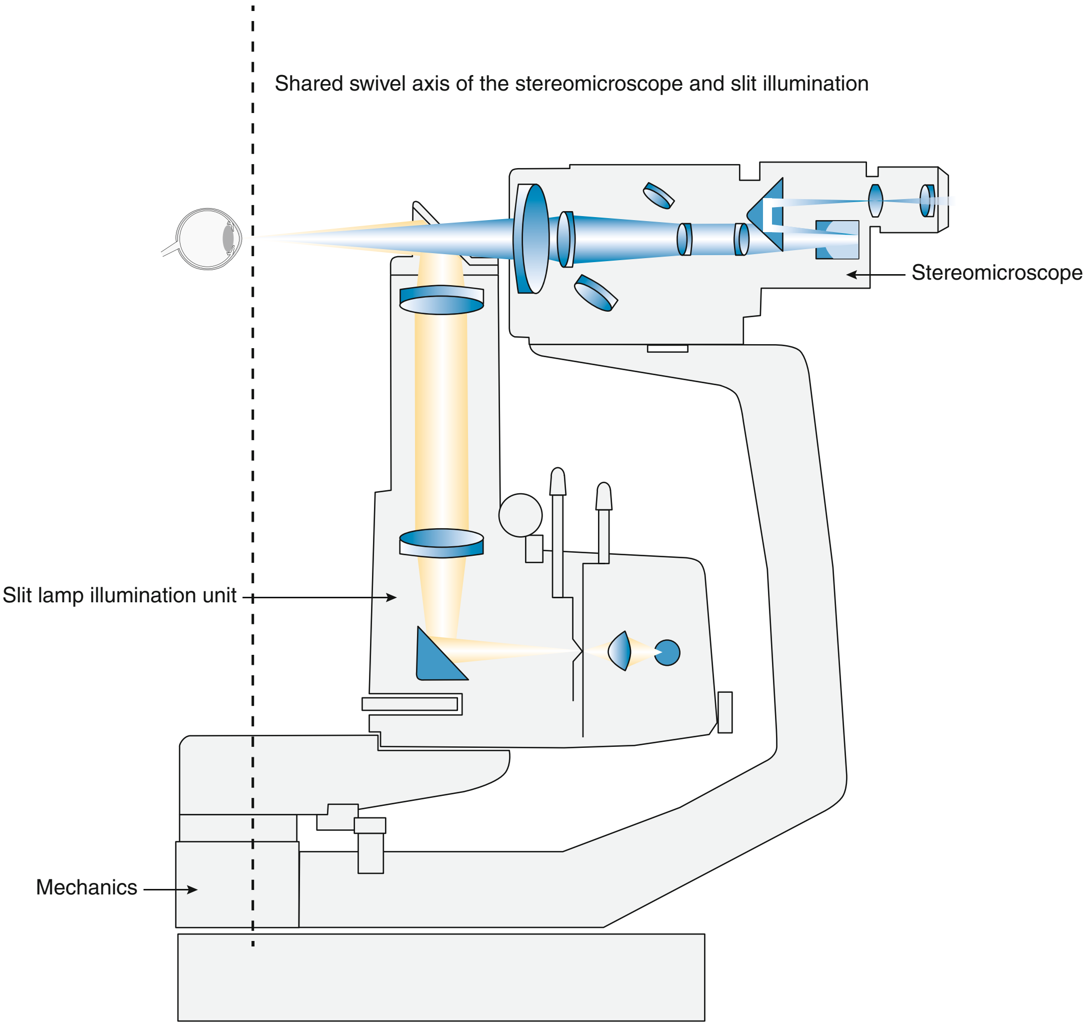

Fig. 1.2 Basic parts of the slit lamp

All the various slit lamps on the market have a mechanical swivel axis that joins the capacities to illuminate and stereoscopically display the eye. They can differ in how the illumination unit aims the light, either from above (Haag-Streit, Figs. 1.3 and 1.4) or below (Zeiss, Fig. 1.1) the microscope. To keep the slit lamp as small and compact as possible, the path of illumination is bent once or twice by prisms (Zeiss) or mirrors (Haag-Streit). These optical elements certainly characterize the slit lamp's appearance as we know it, but they do not reflect the fundamental optical principles of the slit lamp that are elucidated in what follows.

1.1.3 Slit Illuminator (Light Projector)

Slit illumination unit (also known as the slit light projector) is designed to produce a slit beam of maximum brightness on the microscope level

Fig. 1.3 Slit lamp BQ900 (Haag-Streit)

Fig. 1.4 Slit lamp SL-D7 (Topcon)

whose length, width, and position can be changed. In so doing, Köhler's Principle of Illumination is now applied exclusively (Fig. 1.5).

In Gullstrand's original concept in 1911, the light source was initially transmitted via a condenser system in the slit aperture and then focused into the patient's eye with a condensing lens (Gullstrand 1911, 1912). However, when using light sources with a coiled filament, the illumination was irregular. With Köhler's Principle of Illumination, the light source is transmitted to the objective lens via the collector system and through the slit aperture. The objective lens in turn produces an image of the slit aperture in the area being examined. The slit image thus produced is very homogeneous.

A slit lamp's light source can originate from a low-voltage incandescent lamp, a halogen lamp, or light-emitting diodes (LED). In terms of their intensity of illumination and color temperature, halogen lamps tend to resemble an overloaded conventional light bulb, but they have the advantage of lasting longer. Although modern LEDs are even longer-lasting, ophthalmologists try to adapt their color temperature to the examination conditions they are used to from halogen lamps.

1.1.3.1 Optical Transmission

The slit lamp's brightness is intensified by antireflective coating on all the glass surfaces. The illumination loss due to reflective effects is thus reduced (by between 4 and 1.5 %), and with high-grade antireflection, less than 0.5 % of illumination is lost. The total gain in brightness of the slit illumination via antireflective coating is about 20 % higher than that of slit lamps with uncoated glass surfaces.

Most slit lamps have an opaque disc that can be inserted into the optical pathway; it transforms the slit beam into diffusely large light.

A high color temperature is especially desirable in the light source (i.e., a high degree of blue in the light) when performing slit lamp microscopy. Such light is scattered more easily in transparent media, making diagnostically important yellow discoloration easier to detect.

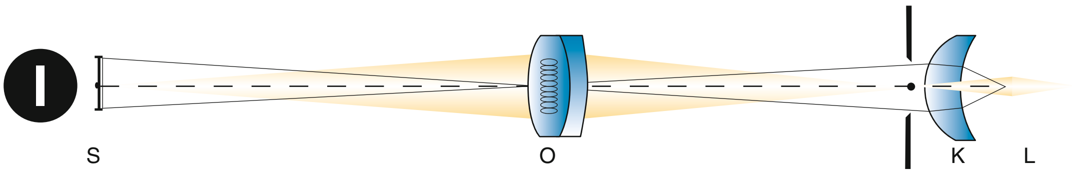

Fig. 1.5 Köhler's Principle of Illumination; the light source *L* is transmitted to the objective lens *O* by the collector system *K*. The objective in turn produces an image at *S* of the slit aperture located next to the collector system

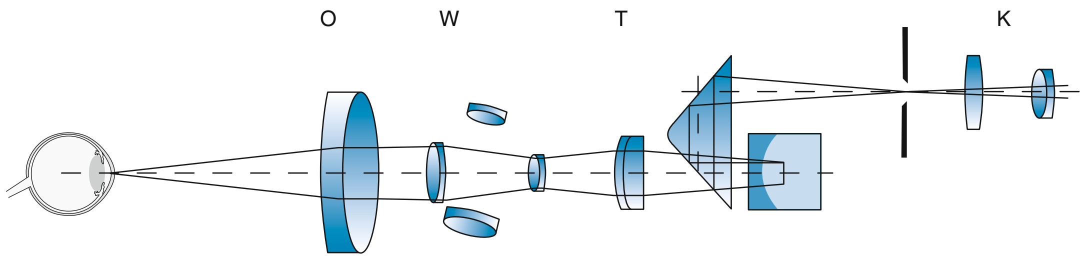

Fig. 1.6 (Lateral view): each eye is allotted its own parallel beam path. The telescopic lens consists of the objective *O*, a stereo tube *T*, and the eyepiece *K*. A telescopic system *W* can be arranged between *O* and *T* permitting variable, total magnification

Other examination methods such as fluorescence assessment when fitting contact lenses require that the light's spectral composition be changed. Various filters in the illumination unit are provided for this purpose which can be easily swung into the beam path. The range of filters includes exciter filters for fluorescence, green filters for contrast enhancement, and sometimes gray filters for reducing the illumination intensity while maintaining the color temperature.

1.1.4 Slit Lamp Microscope

The user expects the slit lamp microscope to provide optimum stereoscopic observation: the size of the field of view and depth of field should be as large as possible, with the space in front of the eye large enough to allow the eye to be manipulated (Fig. 1.6).

The telescopic lens is a fundamental principle associated with the slit lamp; everyday ophthalmic routine demands that we be able to vary their magnification.

1.1.4.1 Principle of a Telescopic Lens

A telescopic lens is based on a telescope and an object-side magnifying lens. The object (the patient's eye) is located in the focal point of the magnifying lens projecting the object image virtually to infinity. This image is then viewed through the telescope.

Transferred to the slit lamp, this means that the eye that the objective has magnified (focal length f1) can be viewed with the corresponding telescopic magnification through the stereo tube (focal length f2) and the ocular (focal length f3). The effect thereof is that each eye has its own parallel beam path between the objective and ocular.

The telescopic lens total angular magnification functions according to the formula below:

$$\begin{aligned}
&\text{Total magnification}\\
&\quad = \text{magnification of the objective lens}\\
&\quad \times \text{magnification of the telescope}\\
&\quad \times \text{magnification of the magnification changer}\\
&\quad = (0.25/\text{f1}) \times (\text{f2}/\text{f3}) \times \text{changer magnification}
\end{aligned}$$

1.1.4.2 Magnification Changer

In practice, the slit lamp requires magnifications ranging between 5-fold and 50-fold, whereby the most commonly used are 10×, 16×, and 25×. The microscope magnification can be varied by changing the eyepieces (the Greenough system), but it is simpler and more elegant to use a magnification changer with variable optical elements.

A tried and tested means of changing the magnification is to insert a Galilean system (Fig. 1.7) with a telecentric optical path between the slit lamp's objective and the stereo tubes. In so doing, the object's plane need not be moved. To allow for multiple magnification options, two small Galilean telescopes are arranged inclining toward each other and usable in both directions in a rotatable drum whose axis is perpendicular to the optical axes. Thus they provide four different powers of magnification.

If two Galilean systems with magnification powers 2.5× and 1.6× are used, the following five magnification options become available: 2.5×, 1.6×, 0.63× (=1/1.6), 0.4× (=1/2.5), and 1× (resulting from the free aperture available on the drum).

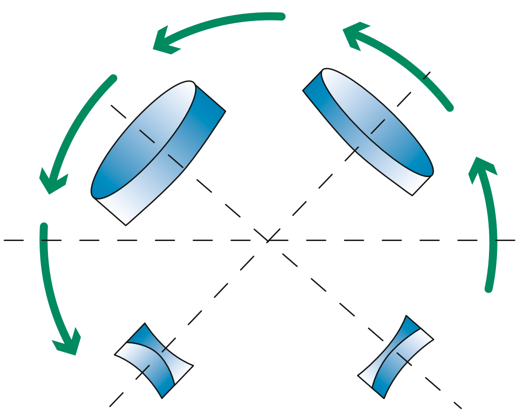

Fig. 1.7 Example of a magnification changer with five power options, with the Galilean telescopic system with, variable magnification powers in a drum used in both directions

1.1.4.3 Binocular Tube

One looks through the slit lamp via the two oculars of a binocular tube, thus guaranteeing a specific distance between the oculars and main objective (=mechanical tube length) (Fig. 1.8).

Stereo microscopes possess either a straight binocular tube (parallel tubes) or a tube that converges. The parallel tubes provide us with a fatigue-free view through the slit lamp for longer periods. However, for examinations in which the practitioner observes the patient's eye alternatively through the slit lamp and with the unaided eye accommodated, a convergent beam path is preferable (i.e., through a convergent tube). After all, when viewing an object up close, our two eyes converge in accommodation.

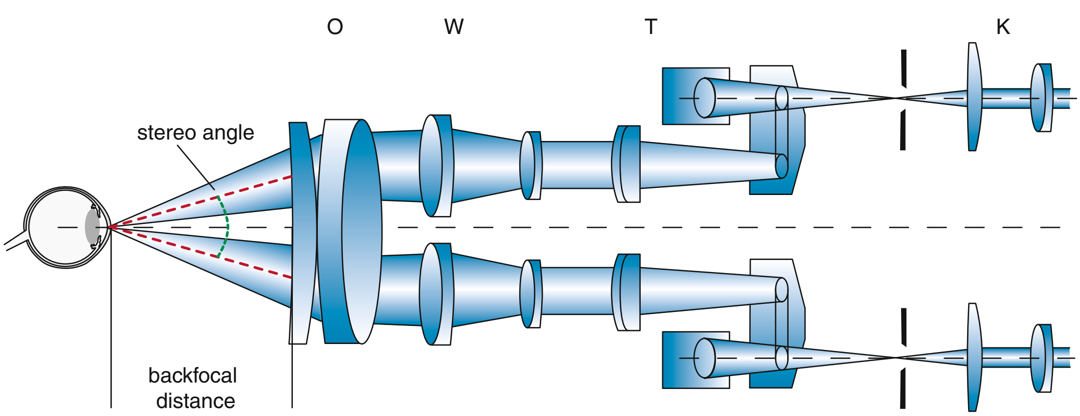

Fig. 1.8 Binocular tube with stereo angle and backfocal distance (the stereo angle is larger than in reality, due to the shortened backfocal distance in the diagram)

1.1.4.4 Physical-Optical Properties of the Slit Lamp Microscope

Besides magnification, slit lamp microscope users are usually interested in the following optical criteria: resolution, brightness, depth of field, stereo angle or stereo base, and backfocal distance.

Resolution

A slit lamp's usual magnification (up to 40×) with a numerical aperture (= sinus of half of the aperture angle) from 0.05 to 0.08 lies in the range of "necessary magnification" as it applies to microscopes.

Brightness

The exit pupils of a good slit lamp microscope (= size of spot of light in the oculars) range between 0.8 and 2.7 mm and are thus narrower than the standard human pupil – thus no light is wasted.

Depth of Field

The depth of field has three components: the depths of focus, accommodation, and resolution.

The demand for maximum brightness conflicts with that of maximum depth of field. Thus a "brighter" slit lamp may have the serious drawback of a lower depth of field if its brightness is not based on the lamp's brightness alone.

Stereo Angle and/or Base

Slit lamp microscopy is based on good stereoscopic vision. The wish to make the convergent angle as large as possible conflicts with the need to observe through limited apertures such as the pupil and contact lens mirrors. This is why good slit lamp microscopes function at a convergent angle measuring between 10° and 15° (Fig. 1.8).

Backfocal Distance

Backfocal distance is another parameter of the slit lamp microscope worthy of special attention. It is the distance between the patient and front surface of the microscope. The backfocal distance must have a certain minimum length to give the practitioner enough room to manipulate the eye. If this distance is excessive, the examiner must assume an awkward arm position, making manipulation difficult. A slit lamp's backfocal distance usually ranges between 90 and 120 mm.

1.1.5 Appliance Mechanics

Today's slit lamps are the result of over 100 years of development. They fulfill the demands of universal application and ease of operation. The illumination unit and stereomicroscope are functionally connected in a mechanical support system, aka instrument base. Although the illumination and stereomicroscope are independent of each other, they share a vertical, isocentric axis and can thus be swiveled independently.

The axis is a virtual extension of the mechanical instrument axis, the point of rotation being located below the patient's eye (Fig. 1.2). The slit is normally focused on the axial plane and can be seen sharply defined at the microscope's focal point. During an examination, the axis of rotation is moved into the position of the object under observation. This is achieved via a mechanical instrument base containing a cross-slide system and carrying the mechanical support axis of the illumination unit and microscope.

The instrument base is moved horizontally via a single control element known as the joystick. The instrument base also contains a vertical control mechanism allowing the slit and viewing axis to be adjusted vertically. This vertical controller is usually integrated in the joystick and is implemented via manual rotation or electronically. Thus, the operator can adjust the slit lamp to accommodate the patient in all three spatial dimensions (the "3-D" joystick lever).

Modern slit lamps not only permit the illumination unit to be swiveled in front of the