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Luminous Flux in Ex-Vivo Porcine Eyes during Endoillumination and during Transscleral Illumination Depending on the Transmission Properties of the Eyewall

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Abstract: (1) Background: During eye surgery, it is important that sufficient light enlightens the inside of the eye for small structures to become visible. The intraocular brightness is influenced by the luminous flux of the illumination system. However, the intraocular luminous flux during surgery has not been investigated so far. Insufficient luminous flux makes vision difficult for the surgeon, whereas excessive luminous flux can cause damage to the retina. Therefore, the luminous flux in lightly and strongly pigmented eyes is determined by endoillumination and diaphanoscopic illumination. (2) Methods: First, the luminous flux emitted from a diaphanoscopic illumination fiber is measured. For determining the intraocular luminous flux, this is multiplied with the transmission properties of the eyewall, which are determined for ex vivo porcine eyes. In order to compare the luminous flux of transscleral illumination with that of endoillumination, the luminous flux of various endoillumination fibers is examined. (3) Results: The results reveal that the total transmission of the eyewall is up to 2.5 times higher for blue/lightly pigmented eyes than for brown/strongly pigmented eyes. With this, the intraocular luminous flux in ex vivo porcine eyes is around 95% higher for less pigmented eyes than for strong pigmented eyes, considering intraocular reflections. (4) Conclusion: To obtain the same brightness in blue and brown eyes, the surgeon can reduce the intensity of the light source when illuminating blue eyes to reduce their retinal risk.

Keywords: transmission; eyewall; luminous flux; diaphanoscopy; endoillumination; pigmentation

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1. Introduction

Diaphanoscopy is an old but well-established method for visualizing the retina and examining the eye, e.g., for foreign bodies and tumors, opacities, and the detection and localization of retinal tears [1–9]. In diaphanoscopic illumination, light is applied to the eyewall from the outside, with the interior of the eye illuminated transsclerally. Therefore, the illumination is attenuated. With this, the luminous flux inside the eye is reduced compared to the luminous flux outside the eye. To our knowledge, there are no known values for the intraocular luminous flux for diaphanoscopic illumination. Usually, only information about the luminous flux of the light source itself or in combination with an optical fiber is available for endoilluminators and chandeliers. Depending on the diameter of the illumination fiber and on the type of light source, the luminous flux differs. For example, xenon lamps emit 25 lm (27G fiber) [10], 29 lm (25G fiber) [11], and 45 lm (23G fiber) [12]. With mercury vapor lamps, the luminous fluxes are 15 lm (30G fiber) [13], 35 lm (29G fiber) [11], and 56 lm (25G fiber) [11]. However, since different light sources or fibers were applied, these results are unfortunately difficult to compare. Both, Berliner Glas KGaA Herbert Kubatz GmbH & Co. (Berlin, Germany) and Geuder AG (Heidelberg, Germany) developed an RGB light source module for endoillumination, which can emit up to 40 lm [14], or 45 lm [15]. Reducing the fiber diameter from 20G to 25G reduces the luminous flux of a xenon lamp from 10–12 lm to 4–5 lm [16]. The development of

an LED chandelier endoilluminator by Hessling et al. (2015) provided a luminous flux of about 11 lm, which is enough to clearly illuminate the retina of ex vivo porcine eyes. Using this LED for transscleral illumination reduced the luminous flux inside the eye to around 2 lm [17,18]. However, this value was not measured but estimated with the scleral transmission at 570 nm. Further development of this transscleral LED illumination by Lingenfelder et al. [19] resulted in a value of 3.5 lm in the eye, which was also estimated with the help of scleral transmission and was not measured directly. Although, Hessling et al. (2015) and Lingenfelder et al. (2017) only considered the sclera and not the total eyewall for the calculation of the intraocular luminous flux. These studies provided the first approximations for the luminous flux with diaphanoscopic illumination. However, to our knowledge, no further information about the intraocular luminous flux during transscleral illumination is available. For the new development of ophthalmic illumination devices, it would be advantageous to know this value in order to be able to apply it as a reference for further illumination systems. A luminous flux that is too low would complicate the surgeon's ability to detect structures or damages in the eye, while excessive luminous flux itself can lead to retinal damage [20].

The aim of this study is to determine the luminous flux inside ex vivo porcine eyes for two different ophthalmic illumination systems (xenon and a halogen lamp) during endoillumination and diaphanoscopic illumination. To determine the luminous flux during diaphanoscopy, the transmission of the eyewall has to be considered. Since the sclera strongly scatters the incident light [21,22], and the choroid and retina absorb parts of the light [23], the expected luminous flux inside the eye differs strongly from that outside the eye. To calculate the luminous flux in the eye, it is necessary to know the transmission of light through the eyewall. The direct transmission was investigated in a previous study by Koelbl et al. (2020) [23]. We extended this study by measuring the total transmittance of the eyewall, which also detects scattered transmitted light and not only the light that passes the eyewall directly. In addition to this study, we also differentiated the results for different pigmented eyes. Similarly, the intraocular flux was examined for the influence of pigmentation. Since light is reflected and scattered at the inner side of the eyewall, which also depends on the pigmentation of the eye [24], we also examined how the consideration of reflection affects the calculation of luminous flux.

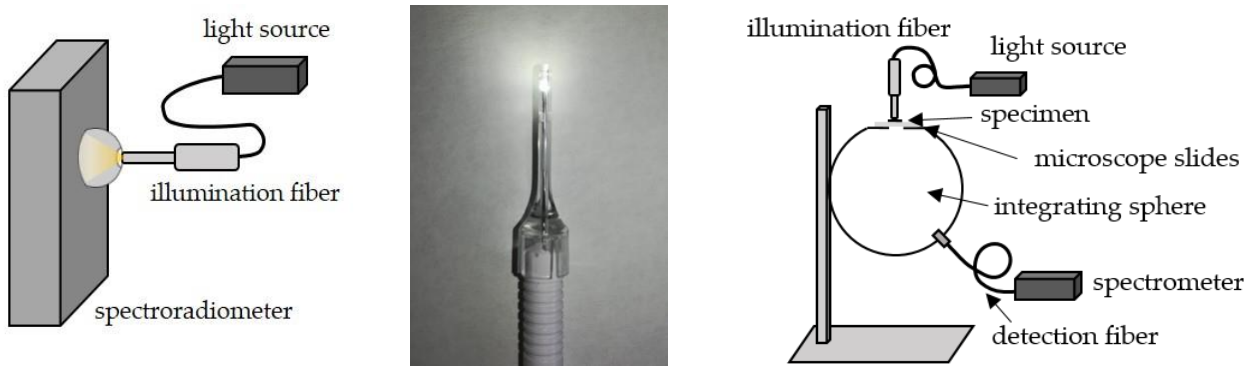
2. Materials and Methods

As a substitute for human eyes, ex vivo porcine eyes were used, as they are a good alternative to human ones due to their similarities in anatomy and physiology [25–27]. The eyes were obtained from a local butcher and were examined on the day of enucleation. They were stored in BSS (balanced salt solution) at 8 °C and divided into two groups, eyes with a blue iris and eyes with a brown/dark iris. Since there is a correlation between fundus pigmentation and iris color [28–30], they were declared as less and high pigmented, respectively. In order to determine the luminous flux in the eye, the eyewall must be examined for its transmission properties. For this purpose, 55 sections of ex vivo porcine eyewalls (sclera, choroidea, and retina) were separated and investigated. Additionally, 42 sections were from eyes with a dark iris and 13 sections were obtained from eyes with a light iris.

The total luminous flux φ_{tot} emitted by ophthalmic illumination fibers is calculated according to Equation (1). For this, the wavelength-dependent luminous flux $\varphi(\lambda)$ has to be measured. A schematic sketch of the measurement set-up is given in Figure 1a. The luminous flux was determined for two different ophthalmic light sources, a halogen light source Accurus Surgical System version 600 DS (Alcon Laboratories Inc., Fort Worth, TX, USA) and a xenon light source BrightStar (D.O.R.C., Zuidland, The Netherlands). Both light sources were set to their maximum possible intensity. Light, which is emitted by the illumination fiber, was detected using a spectroradiometer BTS256-LED (Gigahertz-Optik

GmbH, Türkenfeld, Germany). A list of all investigated illumination fibers is given in Table 1.

$$\varphi_{tot} = \sum_{380\ \mathrm{nm}}^{780\ \mathrm{nm}} \varphi(\lambda)\cdot\Delta\lambda \quad (1)$$



(**a**) (**b**) (**c**)

Figure 1. (**a**) Set-up for luminous flux measurement. The emitted light from the illumination fiber entered the aperture of the integrating sphere of the spectroradiometer. (**b**) Diaphanoscopic illumination fiber with scleral depressor. (**c**) Set-up for transmission measurement. The light from the diaphanoscopic illumination fiber was transmitted through the eyewall into the integrating sphere, which is connected to a spectrometer.

As the inner side of the eyewall reflects light, the luminous flux inside porcine eyes changes. According to [24], this reflection depends on the pigmentation of the eye and on the wavelength. Assuming that the incident light is reflected several times at the eyewall, $\varphi_\lambda\cdot\left(1+R_\lambda^1+R_\lambda^2+R_\lambda^3+\cdots\right) = \varphi_\lambda\cdot\sum_{k=0}^{\infty}R_\lambda^k = \varphi_\lambda\cdot\left(\frac{1}{1-R_\lambda}\right)$, the total value of wavelength- and pigmentation-dependent luminous flux during intraocular illumination is calculated by Equation (2). The data for R have been taken from [24].

$$\varphi_{tot,\mathrm{intra,reflection}}(\mathrm{pigm.}) = \sum_{380\ \mathrm{nm}}^{780\ \mathrm{nm}} \varphi(\lambda)\cdot\frac{1}{1-R(\lambda,\mathrm{pigm.})}\cdot\Delta\lambda \quad (2)$$

To determine the luminous flux inside the eye during diaphanoscopic illumination, the fiber, which includes a scleral depressor (see fiber #3 and #11 in Table 1 but with additional scleral depressor) is applied, which is displayed in Figure 1b. With the luminous flux of this illumination fiber, the intraocular luminous flux $\varphi_{\mathrm{intra,dia}}$ inside the eye can be calculated according to Equation (3). Here, the spectral luminous flux is multiplied by the spectral transmission of the eyewall. As the intraocular irradiance varies depending on eye pigmentation [31], it is assumed that the luminous flux inside the eye also depends on pigmentation.

$$\varphi_{\mathrm{intra,dia}}(\mathrm{pigm.}) = \sum_{380\ \mathrm{nm}}^{780\ \mathrm{nm}} \varphi(\lambda)\cdot T(\lambda,\mathrm{pigm.})\cdot\Delta\lambda \quad (3)$$

The set-up for determining the transmission T(λ,pigm.) of the eyewall is illustrated in Figure 1c. The section of the eyewall was placed with retina down on a microscopic slide and positioned on the aperture of the integrating sphere. A diaphanoscopic illumination fiber was in contact with the sclera and light transmitting the eyewall was detected by the integrating sphere. Similar to Koelbl et al. (2020) [23], the dependence of pigmentation of the eye on its transmission properties was also investigated. The difference here, however, is that, in our study, light from all directions was captured by the integrating sphere, whereas the fiber in studies by Koelbl et al. (2020) could only detect directly transmitted

light without scattered light. We separated the transmission results according to the pigmentation of the eye.

Including the reflection property of the inner side of the eyewall in the calculation of the luminous flux, the intraocular luminous flux during diaphanoscopic illumination changes according to Equation (4). This formula is derived similarly to Equation (3) but with consideration of the transmission properties of the eyewall.

$$\varphi_{\text{intra,dia,reflection}}(\text{pigm.}) = \sum_{380\text{ nm}}^{780\text{ nm}} \varphi(\lambda) \cdot T(\lambda, \text{pigm.}) \cdot \frac{1}{1 - R(\lambda, \text{pigm.})} \cdot \Delta\lambda \tag{4}$$

Table 1. Overview of the applied ophthalmic illumination fibers. Each fiber is assigned a number (# fiber). In addition, the fiber diameter in gauge (⌀ fiber (G)), the intensity of the light source (I (%)), the type of the light source, the manufacturer and, if available, additional information about the fiber is listed.

# Fiber	⌀ Fiber (G)	I (%)	Light Source	Manufacturer of Fiber	Additional Information
1	20	100	halogen	Peregrine (New Britain, PA, USA)	light pipe, endoilluminator
2	20	100	halogen	Peregrine (New Britain, PA, USA)	wide-angle, endoilluminator
3	23	100	halogen	D.O.R.C. (Zuidland, The Netherlands)	TotalView Endoillumination Probe, without scleral depressor
4	23	100	halogen	unknown	endoilluminator
5	23	100	halogen	Alcon Laboratories, Inc. (Fort Worth, TX, USA)	endoilluminator
6	23	100	halogen	Aktive S.r.l. (Roma, Italy)	chandelier
7	23	100	halogen	D.O.R.C. (Zuidland, The Netherlands)	Shielded Total Endoillumination Probe, without scleral depressor
8	25	100	halogen	Alcon Laboratories, Inc. (Fort Worth, TX, USA)	chandelier
9	25	100	halogen	Alcon Laboratories, Inc. (Fort Worth, TX, USA)	MLS Torpedo Mini-Light, chandelier
10	27	100	halogen	D.O.R.C. (Zuidland, The Netherlands)	disposable Eckardt Twinlight Chandelier
11	23	50	xenon	D.O.R.C. (Zuidland, The Netherlands)	TotalView Endoillumination Probe, without scleral depressor
12	23	50	xenon	unknown	endoilluminator
13	23	80	xenon	D.O.R.C. (Zuidland, The Netherlands)	Shielded Total Endoillumination Probe, without scleral depressor
14	27	100	xenon	D.O.R.C. (Zuidland, The Netherlands)	disposable Eckardt Twinlight Chandelier

3. Results

The total luminous flux φ_{tot} emitted by different ophthalmic illumination fibers (#1–14 and Table 1) and the intraocular luminous flux $\varphi_{tot,\text{intra,reflection}}$ are given in Figure 2. Depending on the type of fiber, the diameter of the fiber (20–27G) and the light source, φ_{tot} (gray bars) vary a lot and range between 1.43 and 11.66 lm inside the eye. The intraocular luminous flux, $\varphi_{tot,\text{intra,reflection}}$, in blue and brown eyes (blue and orange bar, respectively) is slightly higher due to the reflection properties of the inner side of the eyewall. Since the reflection in blue eyes is higher than in brown eyes [24], the intraocular luminous flux is also higher in blue than in brown eyes.

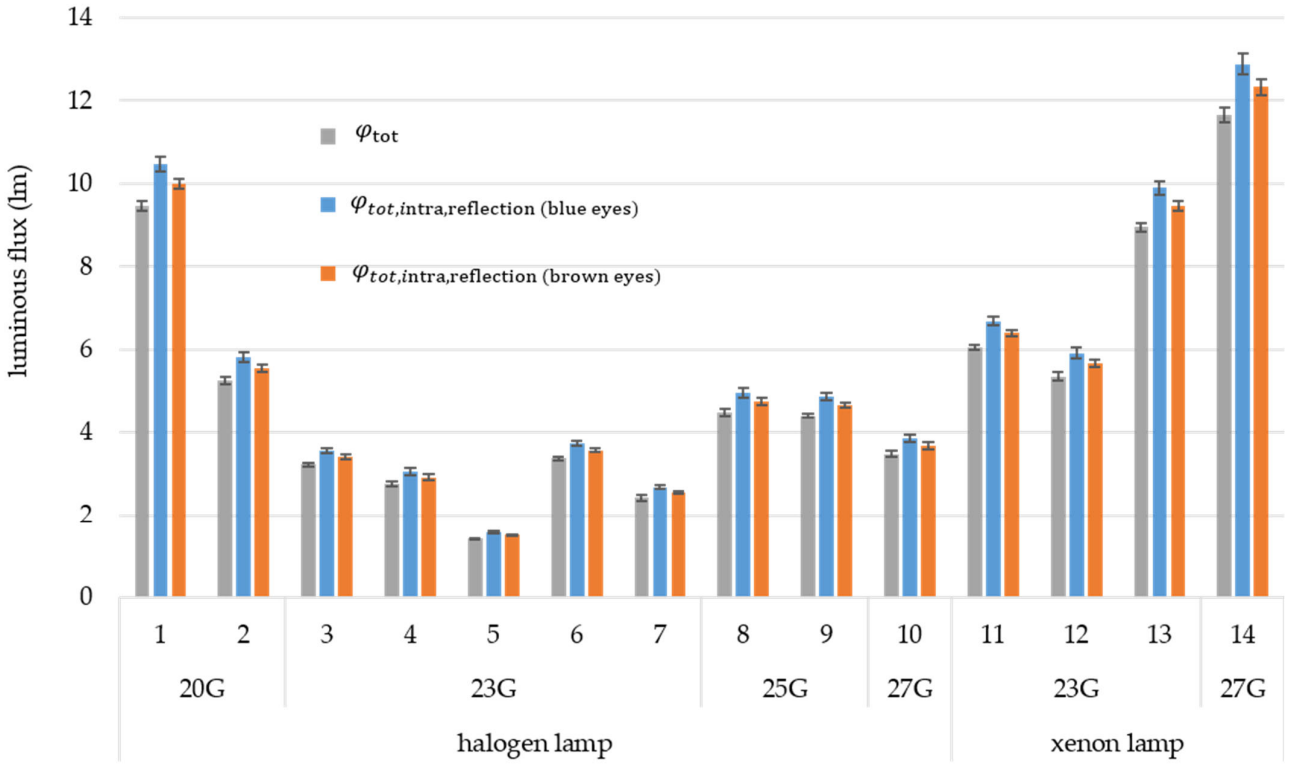


Figure 2. Luminous flux φ_{tot} emitted by different illumination fibers #1–14 with different diameters between 20 and 27G in combination with a halogen or a xenon light source. The calculated luminous flux that is obtained with endoillumination, $\varphi_{tot,intra,reflection}$, is given for low and high pigmented eyes, respectively.

To calculate the luminous flux inside the eye during transscleral illumination, the transmission of the eyewall is needed. The results of the wavelength-dependent transmission of the porcine eyewall are illustrated in Figure 3, separated by the pigmentation of the eye on the left y-axis. The right y-axis presents the ratio of the transmission of blue eyes compared to brown eyes, Q (blue/brown). The transmission increases with increasing wavelength. Additionally, the transmission for less pigmented eyes is higher than for strongly pigmented eyes, especially in the hazardous low wavelength spectrum.

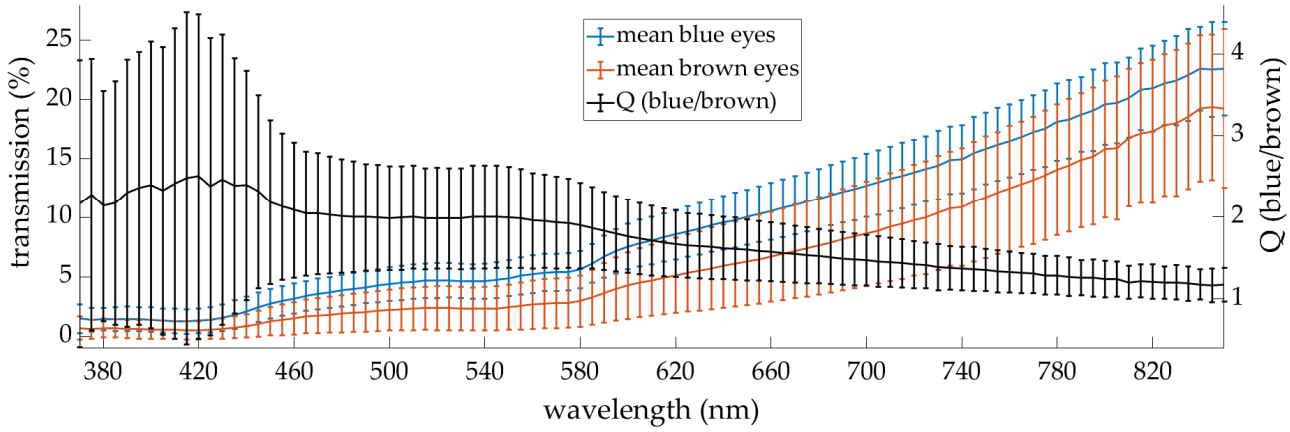


Figure 3. Wavelength-dependent transmission of the porcine eyewall depending on the pigmentation of the eye on the left y-axis and the ratio Q of the transmission of blue eyes to that of brown eyes on the right y-axis with corresponding standard deviation.

With these transmission properties, the intraocular luminous flux during diaphanoscopic illumination is calculated according to Equation (3). In Table 2, the luminous fluxes of the diaphanoscopic illumination fiber (#fiber 3/11 with scleral depressor) in combination with the xenon lamp and the halogen lamp are presented, respectively, with corresponding Gaussian error propagation. φ_{tot} represents the results measured with the set-up illustrated in Figure 1a and calculated according to Equation (1). $\varphi_{tot,\text{intra,reflection}}$ displays the results considering the reflection properties, according to Equation (2). $\varphi_{\text{intra,dia}}$ displays the results that consider the transmission of the eyewall, for different iris color, according to Equation (3) and $\varphi_{\text{intra,dia,reflection}}$ represents the luminous flux inside of the eye during diaphanoscopic illumination, considering the reflection according to Equation (4). The results are divided into results for blue eyes and for brown eyes, respectively. In less pigmented eyes, the intraocular luminous flux during diaphanoscopic illumination, $\varphi_{\text{intra,dia}}$, was higher than in strongly pigmented eyes by a factor 1.86 (halogen lamp) and by 1.87 (xenon lamp). Taking the reflection properties into account, this difference is even higher. The intraocular flux, $\varphi_{\text{intra,dia,reflection}}$, in less pigmented eyes is 1.95 times higher than in strongly pigmented eyes for the halogen lamp and 1.96 times higher for the xenon lamp.

Table 2. Comparison of the luminous flux of the diaphanoscopic illumination fiber in combination with the ophthalmic xenon (fiber #11) and halogen light source (fiber #3) with and without considering the transmission of the eyewall and the intraocular reflection, depending on the iris color.

	Halogen Lamp (Fiber #3)		**Xenon Lamp (Fiber #11)**	
φ_{tot} (lm)	$1.53 \pm 5.2 \times 10^{-2}$		$2.49 \pm 6.5 \times 10^{-2}$	
	blue eyes	brown eyes	blue eyes	brown eyes
$\varphi_{tot,\text{intra,reflection}}$ (lm)	$1.70 \pm 2.2 \times 10^{-2}$	$1.62 \pm 0.7 \times 10^{-2}$	$2.75 \pm 3.4 \times 10^{-2}$	$2.63 \pm 1.1 \times 10^{-2}$
$\varphi_{\text{intra,dia}}$ (lm)	$0.09 \pm 0.5 \times 10^{-2}$	$0.05 \pm 0.6 \times 10^{-2}$	$0.14 \pm 0.7 \times 10^{-2}$	$0.08 \pm 1.0 \times 10^{-2}$
$\varphi_{\text{intra,dia,reflection}}$ (lm)	$0.10 \pm 0.5 \times 10^{-2}$	$0.05 \pm 0.7 \times 10^{-2}$	$0.16 \pm 0.8 \times 10^{-2}$	$0.08 \pm 1.1 \times 10^{-2}$

4. Discussion

Comparing the measured luminous fluxes in this study emitted by different ophthalmic illumination fibers, ranging between 1.43 lm and 11.66 lm (see Figure 2), with luminous fluxes of other lighting systems, ranging between 15 lm and 56 lm [10–16], it can be observed that the values in our study are quite small. This may be due to different fiber geometries, light sources, and different adapters connecting the fiber to the light source. It is also possible that the light sources applied in previous studies were more powerful. The high value for fiber #14 is due to the fact that this is a Twinlight chandelier, which contains two fibers with diameters of 27G. Therefore, the luminous flux is that high and even higher compared to fibers with larger diameters. Due to the fact that different light guides are connected to the light source with different adapters, it is unfortunately difficult to compare data here. In the case of 23G with the halogen lamp, for example, fibers #3, #4, and #7 are connected with the same adapter and emit approximately the same luminous flux. Fibers #5 and #6, on the other hand, each have two different adapters, which makes the comparison more difficult. Here, light is probably not coupled into the fiber in exactly the same way, which leads to a lower and higher luminous flux. Although most of the literature data are somewhat higher than those measured in our study, [10–15], some of the literature reports approximately the same luminous flux as our study [16]. In Oshima et al. (2007) the luminous flux of commercially available endoilluminators ranges between 5 and 15 lm [10], which corresponds with the magnitude of our data. Due to the factors just mentioned, it is not easy to compare the already existing values with the values measured

in our study. What should also be noted is that the BrightStar xenon lamp used in our study indicates the luminous flux it emits on a display. However, these displayed lumens do not fit with the luminous flux emitted by the fiber we measured. For example, when inserting fiber #11, #12, # 13, and # 14, the display shows a value of 22 lm, 22 lm, 24 lm, and 42 lm, but the luminous fluxes measured with our set-up are 6.05 lm, 5.36 lm, 8.96 lm, and 11.66 lm, respectively (see Figure 2). Since only a part of the emitted light from the light source is coupled into the ophthalmic illumination fiber, the luminous flux in front of the fiber tip is smaller than displayed on the light source. In the case of this BrightStar light source, it is assumed that the manufacturer's specifications of the luminous flux displayed corresponds with that of the lamp and not to the fiber emission. As this is not always evident from the available literature data either, it would be necessary to provide uniform information on the luminous flux to be emitted from the illumination fiber in order to obtain sufficient light to illuminate the intraocular space and, on the other hand, not too much light in order to not damage the retina.

This study reveals how the intraocular luminous flux can be determined during diaphanoscopic illumination or endoillumination of the interior of the eye. Another way to illuminate the eye is by direct or indirect ophthalmoscopy. The luminous flux in the eye could then be determined, as described in [32,33], and even the spatial distribution of the luminous flux on the retina can be determined.

When using endoillumination fibers and chandeliers, the brightness in the eye is slightly larger than the brightness of the fiber measured without the use of an eye due to intraocular reflections (see Figure 2). For fibers applied in diaphanoscopic illumination, e.g., fiber #3/11, the brightness inside the eye changes due to the transmission properties of the eyewall. The results in Figure 3 present a higher transmission for blue eyes than for brown eyes. This is due to higher melanin content in the eyewall of brown eyes than in blue eyes [28]. Melanin absorbs strongly at shorter wavelengths and less at longer ones [24]. Another pigment that absorbs in the low wavelength range is hemoglobin [24], which is located mainly in the choroidea. Therefore, the transmission increases with increasing wavelength.

With diaphanoscopic illumination, the luminous flux is low compared to illumination via endoilluminators. This is illustrated in Table 2. With the halogen lamp, fiber #3 emits 1.53 lm, whereas for diaphanoscopic illumination, only a luminous flux of 0.09 lm in blue eyes and 0.05 lm in brown eyes reaches the interior of the eye. For the xenon lamp, the fiber #11 emits 2.49 lm, whereas the same fiber used for diaphanoscopic illumination would provide 0.14 lm in blue eyes and 0.08 lm in brown eyes. Considering the intraocular reflection on the eyewall, the luminous flux in blue eyes changes to 0.10 lm (halogen lamp) and 0.16 lm (xenon lamp). The values for brown eyes do not change due to the smaller reflection compared to blue eyes [24]. This leads to an even higher fraction of luminous flux inside blue eyes compared to brown eyes by a factor of 1.95 (halogen lamp) and 1.96 (xenon lamp). It is clearly demonstrated that with endoillumination, the interior of the eye is more brightly illuminated than with diaphanoscopic illumination. It would be desirable to turn the luminous flux of the diaphanoscopic illumination device so high that the same luminous flux is received in the eye as with endoillumination. However, the risk to the retina must be considered here. Behar-Cohen et al. (2011) revealed that the higher the luminous flux, the higher the risk to the retina [20]. Depending on the luminous flux, the irradiance on the retina is influenced. The more lumens that enter the eye, the higher the irradiance can be detected on the retina. The limit values for irradiances on the retina, weighted with photochemical and thermal hazard weighting function, given in the international standard EN ISO 15004-2:2007 [34] and in [35,36], are based on previous studies carried out on animals. These have been adopted for humans with the intention to include all light/radiation based potential hazards to the retina. These standards give technical guidelines for the assessment of all retinal hazards, which are based on publications by, for example, Ham et al. (1982), Ham et al. (1976) [37,38], and Sliney et al. (2005) [36]. Following these guidelines, it is possible to eliminate or minimize retinal risk. From the

limit values given in [34], the maximum exposure time can be calculated, which must not be exceeded. For example, if the irradiance in blue eyes is twice as high as in brown eyes, and the maximum exposure time of the brown eye would be 60 min, the exposure time for blue eyes would only be 30 min. However, the luminous flux does not increase equally with the irradiance, and thus with the risk to the retina, this relationship would have to be investigated in order to be able to make a statement about the risks to differently pigmented eyes at different luminous fluxes.

Previous studies determining the intraocular luminous flux by diaphanoscopic illumination specify values of around 2 lm and 3.5 lm [17–19]. These values are also higher than the values estimated in our study (see Table 2). However, only scleral transmission is considered in these studies. If the entire transmission of the eyewall is considered, these values would be reduced and the data would probably be more similar to our results.

Generally, the question is how much light is needed inside the eye to gain a clear view and to distinguish small structures. In an overview of the development of a light source for retina illumination, it is a given that a luminous flux of more than 10 lm should exit the light fiber to illuminate the retina with chandelier illumination [39]. Sakahuchi et al. (2011) stated that 30 lm are sufficiently bright and Oshima et al. (2007) claimed that 25 lm are sufficiently bright to obtain a clear wide-angle view in the fundus [10,13]. However, there is no minimum limit that specifies how bright it should be in the eye. For further development of diaphanoscopic illumination, the luminous flux of the light source in combination with an illumination fiber should be so high that, considering the transmission of the eyewall, enough light will still reach the interior of the eye to make it as visible as in endoillumination. Additionally, a risk assessment for the retina must be performed since the illumination is close to the retina and could thus cause nerve damage.

Since the intraocular luminous flux is influenced by the transmission property of the eyewall, a dependence on eye pigmentation can also be observed for the luminous flux. For the surgeon, it is necessary to know that the luminous flux in blue eyes is around 95% higher than in brown eyes. It is also important for the surgeon to know that especially the transmission in the hazardous blue wavelength range of the illumination spectrum is greater for blue eyes than for brown eyes. Therefore, the surgeon could decrease the intensity of the light source in blue eyes to achieve the same brightness he would achieve in brown eyes. This would also reduce the potential retinal damage that can occur with excessive light intensity. A possible way to implement these results would be to include an indication of the patient's eye color in future systems so that the illumination intensity can be adapted to it, thus reducing the risk to the retina.

5. Conclusions

In summary, the luminous flux inside ex vivo porcine eyes during endoillumination (1.7 and 1.62 lm in blue and brown eyes (halogen lamp) and 2.7 and 2.63 lm for blue and brown eyes (xenon lamp)) is much higher than with diaphanoscopic illumination (0.1 and 0.05 lm in blue and brown eyes (halogen lamp) and 0.16 and 0.08 lm for blue and brown eyes (xenon lamp)). The diaphanoscopic luminous flux is calculated with the help of the transmission property of the eyewall. The transmission of the eyewall depends on the level of pigmentation of the eye and is higher for blue eyes than for brown eyes. With this, the luminous flux also depends on the pigmentation of the eye. It is assumed that the results from ex vivo porcine eyes can be transferred to human eyes. Therefore, the surgeon should keep in mind that during transscleral illumination, the luminous flux is higher in blue eyes than in brown eyes. To obtain the same brightness in blue and brown eyes, the surgeon can reduce the intensity of the light source when illuminating blue eyes to reduce their retinal risk.

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