Illumination in Spinal Surgery Depending on Different Approaches and Light Sources

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■ BACKGROUND: **Sufficient visualization of the operating field is crucial for success in surgery and is important especially concerning minimally invasive and deep approaches in spine surgery.**

■ METHODS: **The spinal microsurgical approach was imitated using an isolated box that was accessed with different devices. Different light sources and auxiliary devices were analyzed and compared. Light sources used were a microscope, a standard operating room lamp, and a headlamp. The auxiliary devices included different tubes with and without optical light fibers, different retractors, and an endoscope.**

■ RESULTS: **We demonstrated that different combinations of light sources and auxiliary devices provide significantly different illumination in the artificial operating field. A tube with optical fibers seems to be superior for non-microscopic approaches. The smaller these tubes are in diameter, the higher the illuminance on the surgical focus.**

■ CONCLUSIONS: **The combination of tube and microscope seems to be the best choice for deep approaches in microsurgical spinal surgery. An endoscope supplies illuminance comparable to a surgical microscope.**

INTRODUCTION

Sufficient visualization of the operating field is crucial for success in surgery. Concerning minimal access in modern spinal surgery, sufficient illumination using external light sources becomes less obvious. Besides magnification and stereoscopy, illumination is most important, and, especially concerning minimally invasive and deep approaches, selection of auxiliary devices and light sources is essential. Requirements of lighting in the operating room have previously been the focus of research and described by several authors in different settings.[1-4] Different light-emitting diodes (LEDs) in various surgical scenarios, visual acuity depending on different illuminances in laryngoscopy, visual identification compared with headlamps in otolaryngoscopy, fiberoptic headlamps compared with normal headlights in cardiovascular surgery, and visual or color acuity in 2 types of LED illumination have been analyzed.

To the best of our knowledge, illumination and visualization in spinal surgery has not been examined in an objective experimental setting, especially not in a comparison with endoscopic surgery. Owing to increasing operating techniques, new surgical approaches, and instrumentation techniques, sufficient illumination of the surgical field in spinal surgery is indispensable. New tools for better illumination and magnification, such as microscopes, endoscopes, percutaneous tubular systems, observer displays, and high-definition cameras,[5-9] have been developed and have become standard procedures in spine surgery. In the present study, we compared illuminance as part of ideal visualization beside stereoscopy in an artificial surgical spine field using different light sources and auxiliary devices.

MATERIALS AND METHODS

The spinal microsurgical approach was imitated using an isolated box that was accessed with different devices. Different light sources and auxiliary devices were used and compared. Illuminance was measured with a lux meter (SO 200K Sauter Light Meter; Sauter GmbH, Balingen, Germany) whose sensor was isolated and surrounded by foam material to reduce interference with other external light sources in the environment. The setting used is shown in **Figure 1**.

Key words
- Illumination in surgery
- Light sources
- Neurosurgery
- Spinal surgery

Abbreviations and Acronyms
3D: Three-dimensional
LED: Light-emitting diode

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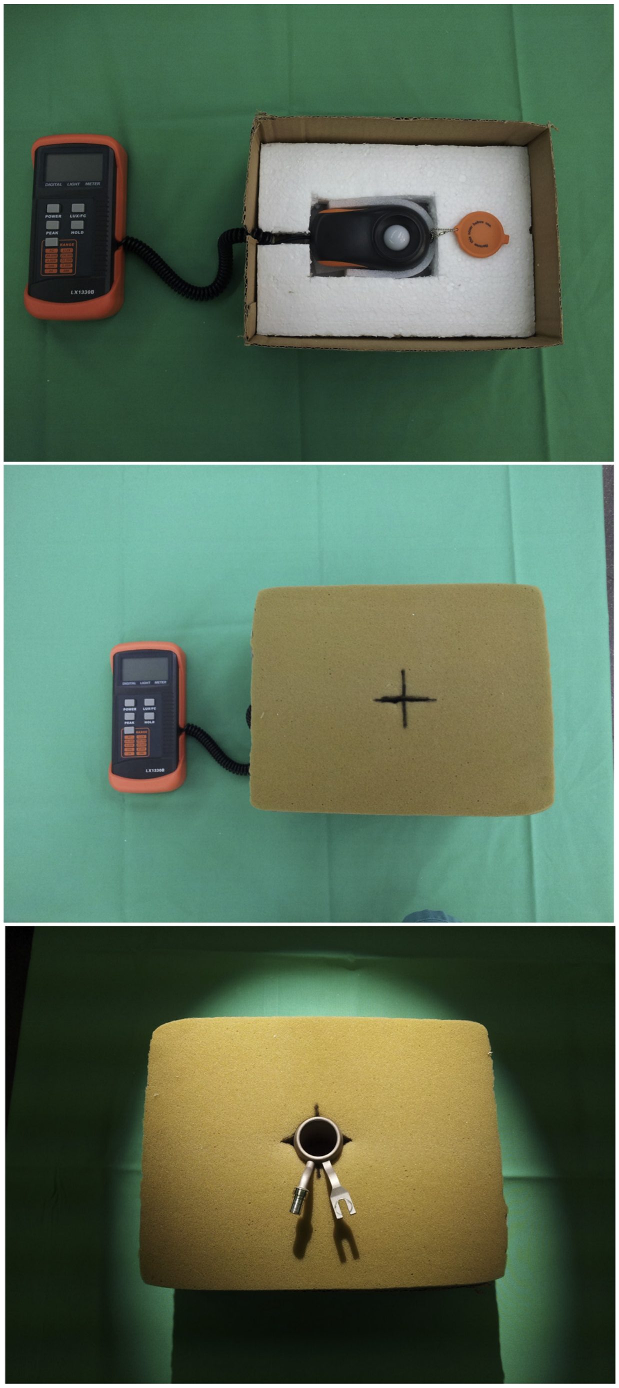

Figure 1. Experimental setting showing an isolated box with lux meter (SO 200K Sauter Light Meter) whose sensor was isolated and surrounded by foam material to reduce interference from other external light sources in the environment. In this example, we used a tube system with optical fibers.

Different tubes (SPOTLIGHT Access System; DePuy Synthes Spine, Raynham, Massachusetts, USA) with 3 different lengths (60 mm, 80 mm, and 110 mm) and 3 different diameters (18 mm, 21 mm, and 24 mm) were used, and models were combined with and without optical light fibers. Furthermore, we examined 2 different retractor systems (Aesculap Spine Classics, BV804R and BV808R; Aesculap AG, Tuttlingen, Germany) with lengths of 64 mm (BV804R) and of 80 mm (BV808R), which were opened to different extents (18 mm, 21 mm, and 24 mm). As a light source, we used a surgical microscope (Pentero; Carl Zeiss Meditec AG, Munich, Germany) with its light intensity adjusted to 10%, 50%, and 100% in a typical distance of 40 cm from the surgical field. Furthermore, an operating room lamp (Hanaulux 2003; Heraeus Med GmbH, Wehrheim, Germany) with a power of 150 W in a distance of 100 cm and a headlamp (Saphiro; Carl Zeiss Meditec AG) with a voltage of 3.7 V and a current of up to 630 mA in a distance of 50 cm were analyzed as light sources. The spots of these light sources were centered to the sensor of the lux meter, and the combined auxiliary device was adjusted in 1 line between light source and sensor. Distances simulated typical operating conditions in spinal surgery. In addition, an endoscope (VERTEBRIS; Richard Wolf GmbH, Knittlingen, Germany) with optical fibers and without any retractors was used. For each combination of light source and approach, 10 illuminances were acquired. Correlations between illuminance, diameter of the tube, extent of opening the retractor system, and length of tubes or retractors were calculated. Furthermore, illuminances between retractors and tubes of the same length were compared with different light sources.

A multivariate analysis with the factor “approach” (retractor vs. tube) and the covariates “longitude” and “width of the approach” was calculated for the different light sources using the general linear model[10] To access the correlation between diameter of tubes or extent of retractors and the measures of illuminance, Pearson correlation coefficient[11] was determined. According to Bonferroni correction,[12] a probability value of $P < 0.07$ for correlation and $P < 0.01$ for multivariate analysis was considered statistically significant. For statistical analyses, IBM SPSS Statistics Version 22 for Windows (IBM Corp., Armonk, New York, USA) was used.

RESULTS

Correlations between diameter of tubes or extent of opening the retractor systems and the measured illuminance were determined. Illuminance correlated to the diameter of tubes using an operating room lamp ($r = 0.816$), a headlamp ($r = 0.625$), a microscope with 10% maximal power ($r = 0.964$), a microscope with 50% maximal power ($r = 0.964$), and a microscope with 100% maximal power (all $P < 0.001$) (Figure 2). Furthermore, illuminance correlated positively with the extent of opening the retractor system (lamp, $r = 0.829$; headlamp, $r = 0.786$; microscope 10%, $r = 0.741$; microscope 50%, $r = 0.759$; and microscope 100%, $r = 0.772$; all $P < 0.001$). When using a tube with an optical fiber, there was a negative correlation of illuminance to diameter ($r = -0.565$, $P < 0.001$); that is, the smaller the tubes in diameter, the higher the illuminance on the surgical focus (Table 1).

Using a tube with an optical fiber provided a higher illuminance than a tube without an optical fiber of the same length and diameter in combination with the operating room lamp in 7 of 9