The Journal of Laryngology & Otology

cambridge.org/jlo

Main Article

# Temperature and luminosity outputs of endoscopes used in transcanal endoscopic ear surgery: an experimental study

T D Milner, M Jaffer and A Iyer

Department of Otolaryngology, University Hospital Monklands, NHS Lanarkshire, Airdrie, Scotland, UK

Mr T D Milner takes responsibility for the integrity of the content of the paper

Presented at the ENT Scotland Winter Meeting, 8 November 2019, Stirling, Scotland, UK, and at the British Academy Conference in Otolaryngology (BACO), 10–12 January 2021 (virtual conference).

**Cite this article:** Milner TD, Jaffer M, Iyer A. Temperature and luminosity outputs of endoscopes used in transcanal endoscopic ear surgery: an experimental study. *J Laryngol Otol* 2023;**137**:368–372. https://doi.org/10.1017/S0022215122001013

Accepted: 12 April 2022
First published online: 29 April 2022

**Key words:**
Endoscopes; Temperature; Otology; Middle Ear

**Author for correspondence:**
Mr Thomas Daniel Milner,
Department of Otolaryngology,
University Hospital Monklands,
Airdrie ML6 0JS, Scotland, UK
E-mail: tommilner1@doctors.org.uk



## Abstract

**Objective.** To establish the relationship between endoscope temperatures and luminosity with a variety of light source types, endoscope ages, endoscope sizes, angles and operative distance in transcanal endoscopic ear surgery.

**Methods.** Transcanal endoscopic ear surgery was simulated in an operating theatre using 7 mm plastic suction tubing coated in insulating tape. An ATP ET-959 thermometer was used to record temperatures, and a Trotec BF06 lux meter was used to measure luminosity. Luminosity and temperature recordings were taken at 0 mm and 5 mm from the endoscope tip.

**Results.** Thermal energy transfer from operating endoscopes is greatest when: the light intensity is high, there is a light-emitting diode light source and the endoscope is touching the surface. Additionally, larger-diameter endoscopes, angled endoscopes and new endoscopes generated greater heat.

**Conclusion.** It is recommended that operative light intensity is maintained at the lowest level possible, and that the surgeon avoids contact between patient tissues and the endoscope tip.

## Introduction

Transcanal endoscopic ear surgery has gained popularity in the field of otology, and has been increasingly adopted to perform tympanoplasty, stapedectomy and cholesteatoma surgery. The enhanced image quality and potential for a wider view of the surgical field has led to the adoption of transcanal endoscopic ear surgery, either as an adjunct to microscopic surgery or as a replacement. The safety profile of endoscopic ear surgery appears to be comparable to that of microscopic surgery, with low complication rates and equivalent success rates.[1,2] However, some studies have highlighted a potential operative risk: the heat generated by the light sources used in endoscopes.[3–10]

Multiple studies have highlighted the impact of temperature rises in ear surgery, including alteration of cochlear microphonics,[4,6] reduced otoacoustic emissions and auditory brainstem responses,[7] and production of a caloric effect.[8] Furthermore, studies have found evidence of direct tissue damage when the tip of these endoscopes comes into contact with local tissue.[10] A study by Turner *et al.* also attributed reactivation of herpes simplex virus and facial nerve palsy to the raised temperatures in endoscope use.[9]

Various studies have assessed the risk of elevated intra-operative temperatures in endoscopic ear surgery. These were carried out in a variety of settings, including three-dimensional (3D) printed temporal bone models,[5] *in vivo* animal models,[8] human cadaver models[4] and live patients.[11] However, many of these studies only investigated light intensity of 50–100 per cent using a 0-degree telescope, even though a previous study had shown that transcanal endoscopic ear surgery can be safely performed at light intensities as low as 10 per cent.[12] A comprehensive assessment of the different factors that affect endoscope temperature would help in fully addressing this question.

This is the first study of its kind to measure luminosity using a lux meter rather than solely relying on light source settings. This study also aimed to gain greater clarity on: low light settings starting at 10 per cent, the impact of closer proximity reached by angled endoscopes to middle-ear structures compared with 0-degree endoscopes, and the effect of new endoscopes compared with older endoscope models. These variables have previously not been considered together in a succinct experimental study.

## Materials and methods

### *Study setting*

This study was undertaken at the University Hospital Monklands, with all measurements recorded by a single researcher. Transcanal endoscopic ear surgery was simulated in an operating theatre using 7 mm plastic suction tubing coated in insulating tape to simulate an external ear canal, with the length of the tubing either 5 mm longer than or equal to the tip of the endoscope. All measurements were recorded on the same surface (Figure 1).


**Fig. 1.** (a) The set up used to simulate transcanal endoscopic ear surgery using a 7 mm plastic suction tubing, coated in insulating tape, to simulate an external ear canal. (b) The end showing the endoscope tip 5 mm away from the end of tubing. (c) Temperature measurement technique. (d) The luminometer used in the study.

Operating theatre lighting and temperature were standardised throughout the study, and confirmed by baseline temperature and luminosity testing.

### *Experimental design*

The ATP™ ET-959 high accuracy dual input K-type/J-type thermometer was used to record temperatures, while the Trotec® BF06 lux meter was used to measure luminosity. For each experimental condition, luminosity and temperature recordings were taken at 0 mm and 5 mm from the endoscope tip. The factors assessed included: the operative light source (light-emitting diode (LED) (Stryker™ L9000 LED and Storz® Power LED 175 light sources) versus halogen (Storz 201133 20 and Olympus CLK-4 halogen light sources) versus xenon (Stryker X8000 light source)), new versus old endoscopes, 0-degree versus angled endoscopes, 3 mm versus 4 mm endoscopes, varied light source intensities, and time since light source illumination (0, 30, 60 and 180 seconds).

### *Statistical analysis*

Normality of the three dependent variables (luminosity, temperature at 0 mm and temperature at 5 mm from the endoscope tip) was confirmed with Kolmogorov–Smirnov and Shapiro–Wilk testing. Independent variables were tested for differences between groups using the student's *t*-test, and were tested for correlations using the Pearson's rank correlation coefficient. Statistical analyses were conducted using R statistical software through RStudio® software (version 1.1.463). Values of $p < 0.05$ were considered statistically significant.

## Results

In total, 12 different endoscopes were assessed. These varied in terms of: manufacturer (Wolf ($n = 6$), Storz ($n = 5$) or Stryker ($n = 1$)), size (3 mm ($n = 5$) or 4 mm ($n = 7$)), age (new ($n = 2$) or used ($n = 10$)) and angulation (0-degree ($n = 7$) or angled ($n = 5$)) (Table 1). In addition, three different light bulb types were trialled, comparing LED (Stryker L9000 LED and Storz Power LED 175), halogen (Storz 201133 20 and Olympus CLK-4) and xenon (Stryker X8000) light sources.

### *Light source*

Surprisingly, in our study, LED light sources generated higher temperatures in comparison to halogen or xenon bulbs. When testing the light cable without an endoscope, at maximum light intensity and following 180 seconds of exposure, LED light sources generated temperatures between 116°C and 174.3°C; in comparison, halogen light sources generated temperatures between 61.9 and 98°C, and xenon light sources generated a temperature of 62°C.

Reassuringly, the temperatures at the tip of the endoscope were significantly lower: when assessing temperatures and luminosity with a range of endoscopes of different sizes, angulation, age and model, at maximum light intensity and following 180 seconds of exposure. The LED light sources generated temperatures of 22.4–44.1°C and luminosity of 510–3800 lumens. Halogen light sources generated temperatures of

https://doi.org/10.1017/S0022215122001013 Published online by Cambridge University Press

**Table 1.** Endoscopes utilised in study

| Endoscope | Age | Manufacturer | Size (mm) | Angled? | Temperature at 0 mm from tip (°C) | Temperature at 5 mm from tip (°C) | Luminosity (lux) |
|---|---|---|---|---|---|---|---|
| A1 | New | Storz | 3 | Yes | 36.7 | 25.3 | 1790 |
| A2 | New | Storz | 3 | No | 37.3 | 31.5 | 1830 |
| A3 | Old | Storz | 3 | Yes | 26.6 | 21.5 | 510 |
| A4 | Old | Wolf | 4 | Yes | 41.2 | 30.4 | 2200 |
| A5 | Old | Wolf | 4 | No | 35.8 | 30.2 | 2300 |
| A6 | Old | Storz | 3 | No | 22.4 | 20.7 | 1260 |
| A7 | Old | Wolf | 4 | Yes | 29 | 26.5 | 1840 |
| A8 | Old | Stryker | 4 | No | 26.5 | 21.1 | 2500 |
| A9 | Old | Wolf | 4 | No | 40.1 | 31.7 | 2900 |
| A10 | Old | Wolf | 4 | Yes | 44.1 | 31.9 | 3800 |
| A11 | Old | Storz | 3 | No | 41.6 | 37.7 | 3000 |
| A12 | Old | Wolf | 4 | No | 25.4 | 24.4 | 520 |

The temperature and luminosity measurements shown were recorded at 100 per cent light source intensity with a light-emitting diode source.

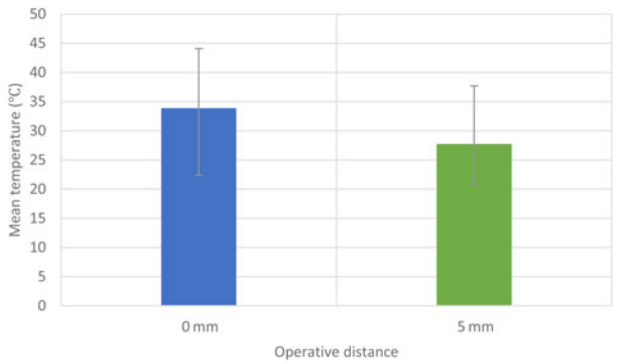


**Fig. 2.** Bar chart demonstrating mean temperatures for all endoscopes when recorded either at the endoscope tip (0 mm) or at 5 mm from the endoscope tip. Error bars represent the minimum and maximum values recorded.

26.5–41.6°C and luminosity of 520–3000 lumens. Xenon light sources generated temperatures of 21.4–25.4°C and luminosity of 168–620 lumens. The Storz LED and halogen light sources produced higher luminosity and temperatures compared with their respective Stryker and Olympus counterparts.

### Old versus new endoscopes

Two new endoscopes were sourced from Storz and directly compared with used models of the same endoscope. A new angled endoscope (Stryker 3 mm, 30-degree) reached a luminosity of 1790 lumens and a highest temperature of 36.7°C, while a used model of the same angled endoscope reached a luminosity of 510 lumens with the highest temperature 26.6°C. Similarly, a new 0-degree endoscope (Stryker 3 mm, 0-degree) reached a luminosity of 1830 lumens and a temperature of 37.3°C, while a used 0-degree endoscope of the same model reached a luminosity of 1260 lumens and a temperature of 22.4°C.

### Zero-degree versus angled endoscopes

The luminosity and temperature production of 0-degree endoscopes were compared with those of angled endoscopes. The mean maximal tip temperature was 32.7°C for 0-degree endoscopes compared with 35.5°C for angled endoscopes, without a significant difference between groups ($t = 0.62$, df = 10, $p = 0.549$). Similarly, the mean luminosity in the 0-degree endoscopes (2044 lumens) in comparison to the mean luminosity in the angled endoscope group (2028 lumens) was also not significantly different ($t = 0.027$, df = 10, $p = 0.979$).

### Size 3 mm versus 4 mm endoscopes

Temperature and luminosity were compared between 4 mm and 3 mm endoscopes. Higher mean temperatures and mean luminosity levels were noted in 4 mm endoscopes (34.6°C and 2294 lumens, respectively) in comparison to 3 mm endoscopes (32.9°C and 1678 lumens, respectively). However, neither of these differences was statistically significant.

### Temperature at tip versus 5 mm from tip

When comparing temperatures produced by the endoscopes, measurements were taken with the thermometer touching the tip and with the thermometer placed 5 mm from the tip. There was a statistically significant difference between temperature measurements when taken at the tip of the endoscope (mean = 33.9°C) and when measured 5 mm from the tip (mean = 27.7°C) ($t = 5.63$, df = 11, $p < 0.005$) (Figure 2).

### Light intensity versus temperature

There was a strong positive correlation between luminosity and temperature, whereby the greater the luminosity, the higher the temperature noted at the tip and 5 mm from the endoscope tip. These correlations were statistically significant for measurements taken at the tip of the endoscope ($R = 0.77$, $p = 0.004$) and for those taken at 5 mm from the endoscope tip ($R = 0.67$, $p = 0.016$) (Figure 3). Temperature rises also demonstrated a logarithmic pattern of increase over time (Figure 4), with a gradual reduction in the rate of temperature increase between 0 and 180 seconds. This was most evident at higher light intensities.

https://doi.org/10.1017/S0022215122001013 Published online by Cambridge University Press

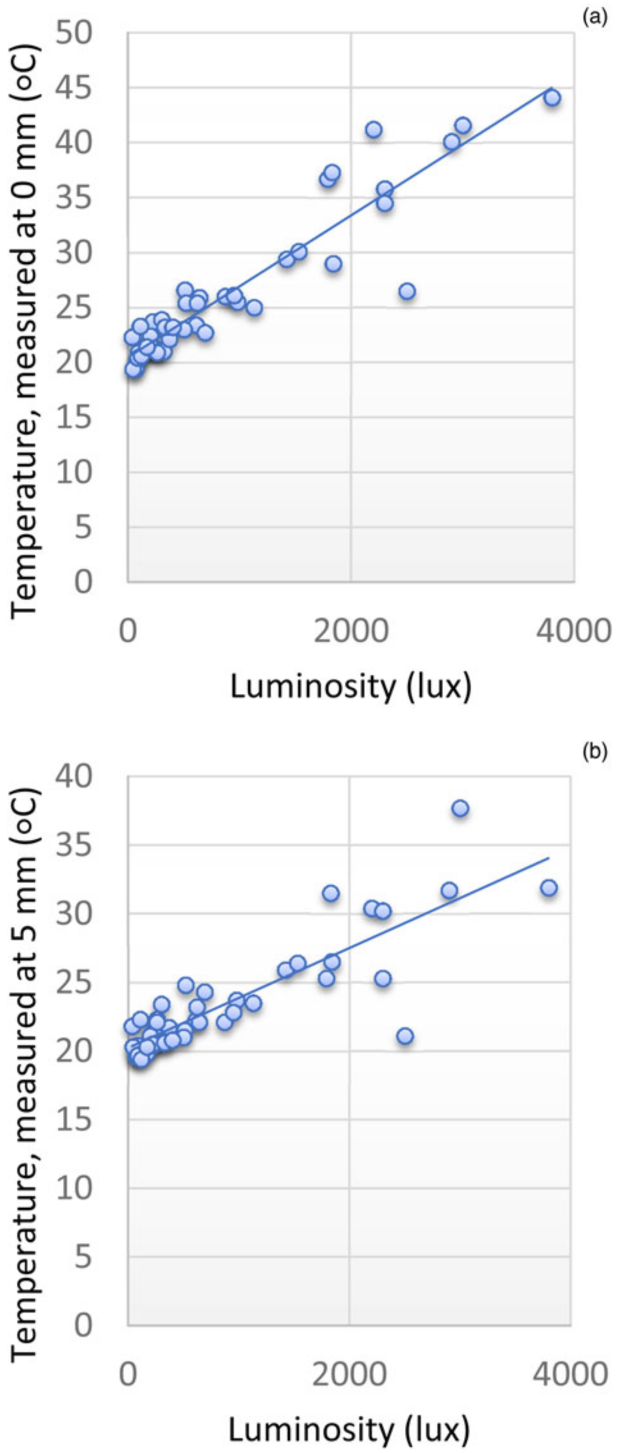


**Fig. 3.** Line graph demonstrating a positive linear correlation between temperature and luminosity.

## Discussion

This study has taken a unique approach by measuring luminosity using a lux meter rather than solely relying on light source settings. Additionally, this study has considered an extensive list of variables, which have previously not been considered together in a succinct experimental study.

We have demonstrated that thermal energy transfer from operating endoscopes is greatest when the light intensity is high and when the endoscope is touching the surface. Furthermore, new endoscopes appear to generate more heat in comparison to older endoscopes, and, in contrast to some other studies, LED light sources generate the greatest temperature and luminosity.

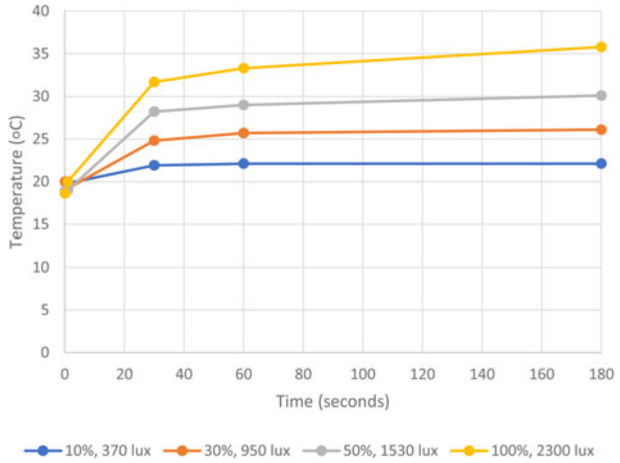


**Fig. 4.** Example line graph demonstrating the logarithmic relationship between temperature increase (recorded at the endoscope tip (0 mm)) and time, for an old, 0-degree, Wolf endoscope.

The thermal energy generated by operating endoscopes has been linked to the ignition of drapes and damage to skin,[13,14] and altering of the workings of the inner ear.[4,6–8,11] However, the maximal temperature achieved has varied greatly amongst the different papers studied. For example, Hensman *et al.* noted temperatures as high as 225°C within 10 minutes of switching on the light source.[15] Conversely, Kozin *et al.* demonstrated temperatures of 46°C at 0.5–1 mm from the tip of the endoscope.[4] Our study therefore aimed to determine what factors led to these variances in temperature.

The effects of high temperatures on body tissues has been assessed in several studies. Guinea pig models, exposed to high temperatures produced by a xenon light source for 5 minutes, showed lower distortion product otoacoustic emissions and an increased auditory brainstem response threshold.[7] Similarly, Kahana *et al.* noted changes to multiple aspects of cochlear microphonics in the hamster cochlea when temperatures rose only to 39°C.[6] Vestibular dysfunction was reported by Bottrill *et al.* when a temperature rise in the ear caused caloric stimulation.[8] Various studies have specifically investigated the propensity for tissue damage and damage to the inner workings of the ear associated with the thermal energy generated by endoscopes used in ENT.[4,7,8,10,16–18] However, thus far, only one paper has reported thermal-related injury in a patient undergoing otology surgery.[11] Das *et al.* demonstrated audiometric change in higher frequencies, which was greater with xenon light sources. Vomiting, vertigo and tinnitus were also noted in patients exposed to either xenon or LED light sources.[11]

While the maximal temperature recorded in the study, from an exposed light cable, was 174.3°C, the maximal temperature at the tip of the endoscope, in any experimental condition, was 44.1°C. Furthermore, temperatures recorded at lower light intensities were significantly decreased. This trend has been demonstrated in previous studies. Tomazic *et al.* reported temperatures as high as 91.4°C at 100 per cent light intensity with a xenon light source, which decreased to 44.3°C at 33 per cent light intensity.[10] Ito *et al.* measured the safety of heat generated by endoscopes with xenon and LED light sources in a 3D model of a human temporal bone.[5] It was noted that a xenon light source generated more thermal energy at 100 per cent light intensity than at 30 per cent intensity.[5] Importantly, the use of a lower light intensity intra-operatively

https://doi.org/10.1017/S0022215122001013 Published online by Cambridge University Press

is feasible: McCallum *et al.* demonstrated no detriment to image quality as a result of the very low light levels used, as low as 10 per cent, which was in turn associated with lower heat generation.[12]

This study also demonstrated a significant increase in temperature recordings when the endoscope tip was in contact with the thermometer. This highlights the importance of avoiding resting the endoscope tip on operative surfaces, particularly in areas that may be sensitive to thermal damage. Other factors studied included: endoscope diameter, angled endoscopes versus 0-degree endoscopes, and whether the endoscope was new or used. Larger-diameter endoscopes, angled endoscopes and new endoscopes appeared to generate greater heat; however, none of these factors achieved significance. While some studies have demonstrated higher thermal energy production from endoscopes with larger diameters,[7,16] because of the minimal temperature difference in larger-diameter endoscopes measured in this study, the authors would not advocate this as a reason for selecting smaller endoscopes.

Our study investigated the maximum temperatures reached at 0, 30, 60 and 180 seconds after switching on different light sources at 100 per cent intensity. Previous studies have investigated temperatures reached up to 30 minutes after the light source was switched on, although a number of studies showed that maximum temperatures were reached within 60 seconds of switching on the light source.[4,7,10,16] This appeared to be the case in our study, with temperature change over time demonstrating a logarithmic pattern of increase, with the greatest temperature rise within the first 60 seconds (Figure 4). These findings suggest that operative pauses, while rapidly cooling the endoscope,[4] are unlikely to be of benefit overall to the patient because of the rapid return to close to maximal temperatures. One additional method to avoid excessive heat exposure within the ear is frequent aspiration and irrigation, and this could be adopted intra-operatively.[19]

- Temperature rise in ear surgery has been linked to: cochlear microphonic alteration, reduced otoacoustic emissions and auditory brainstem responses, caloric effect, and direct tissue damage
- This study found a strong positive correlation between luminosity and temperature, whereby greater luminosity was associated with higher temperature
- Light-emitting diode sources generated higher temperatures and luminosity, compared to halogen or xenon bulbs
- Higher temperatures were recorded from endoscopes with larger diameters, angled endoscopes and new endoscopes, but differences were not significant
- It is recommended that operative light intensity is maintained at the lowest possible level, and that surgeons avoid contact between patient tissues and the endoscope tip

While there were attempts to optimise the experimental design, this study does have some limitations. It was only possible to assess 12 endoscopes, as these were the only otological endoscopes available for study in the department. This led to a small sample size, which could have affected statistical outcomes. The authors argue, however, that if the influence of a particular factor on intra-operative temperatures would only be significant with a large sample size, its relevance clinically would be minimal. In addition, the plastic tubing and matt black surface will not have accurately simulated the middle-ear environment. However, it was not feasible to use animal or cadaveric tissue with the luminosity meter or in the operating theatre environment; furthermore, it would not have been possible to test as many endoscopes without this simulation.

## Conclusion

This study has demonstrated that light intensity and contact with the temperature sensors significantly elevated operative temperatures. In addition, new endoscopes and LED light sources appeared to generate greater heat. The authors of this study would therefore recommend that operative light intensity is maintained as low as possible, and that the surgeon avoids contact between patient tissues and the endoscope tip. For maximal assurance, the surgeon could consider testing the maximal temperature of any new endoscope to ensure it is a safe operative tool.

**Acknowledgement.** Funding for equipment was provided by ENT Scotland.

**Competing interests.** None declared

## References


1 Kozin ED, Gulati S, Kaplan AB, Lehmann AE, Remenschneider AK, Landegger LD *et al.* Systematic review of outcomes following observational and operative endoscopic middle ear surgery. *Laryngoscope* 2015;**125**:1205–14
2 Fradeani D, Milner TD, Iyer A. Learning curve in endoscopic tympanoplasties: a prospective study based on outcomes of 141 cases. *Clin Otolaryngol* 2021;**46**:888–92
3 Mitchell S, Coulson C. Endoscopic ear surgery: a hot topic? *J Laryngol Otol* 2017;**131**:117–22
4 Kozin ED, Lehmann A, Carter M, Hight E, Cohen M, Nakajima HH *et al.* Thermal effects of endoscopy in a human temporal bone model: implications for endoscopic ear surgery. *Laryngoscope* 2014;**124**:E332–9
5 Ito T, Kubota T, Takagi A, Watanabe T, Futai K, Furukawa T *et al.* Safety of heat generated by endoscope light sources in simulated transcanal endoscopic ear surgery. *Auris Nasus Larynx* 2016;**43**:501–6
6 Kahana L, Rosenblith WA, Galambos R. Effect of temperature change on round-window response in the hamster. *Am J Physiol* 1950;**163**:213–23
7 Aksoy F, Dogan R, Ozturan O, Eren SB, Veyseller B, Gedik O. Thermal effects of cold light sources used in otologic surgery. *Eur Arch Otorhinolaryngol* 2015;**272**:2679–87
8 Bottrill I, Perrault DF Jr, Poe D. In vitro and in vivo determination of the thermal effect of middle ear endoscopy. *Laryngoscope* 1996;**106**:213–16
9 Turner MT, Nayak S, Kuhn M, Roehm PC. The effects of dexamethasone and acyclovir on a cell culture model of delayed facial palsy. *Otol Neurotol* 2014;**35**:712–18
10 Tomazic PV, Hammer GP, Gerstenberger C, Koele W, Stammberger H. Heat development at nasal endoscopes' tips: danger of tissue damage? A laboratory study. *Laryngoscope* 2012;**122**:1670–3
11 Das A, Mitra S, Agarwal P, Sengupta A. Prolonged intra-operative thermal exposure in endoscopic ear surgery: is it really safe? *J Laryngol Otol* 2020;**134**:727–31
12 McCallum R, McColl J, Iyer A. The effect of light intensity on image quality in endoscopic ear surgery. *Clin Otolaryngol* 2018;**43**:1266–72
13 Sandhu H, Turner R, Pozo JL. No smoke without fire--simple recommendations to avoid arthroscopic burns. *Knee* 2002;**9**:341–6
14 Bellina JH, Haas M. Cold light sources. Are they really cold? *J Reprod Med* 1984;**29**:275–7
15 Hensman C, Hanna GB, Drew T, Moseley H, Cuschieri A. Total radiated power, infrared output, and heat generation by cold light sources at the distal end of endoscopes and fiber optic bundle of light cables. *Surg Endosc* 1998;**12**:335–7
16 MacKeith SA, Frampton S, Pothier DD. Thermal properties of operative endoscopes used in otorhinolaryngology. *J Laryngol Otol* 2008;**122**:711–14
17 Nelson JJ, Goyal P. Temperature variations of nasal endoscopes. *Laryngoscope* 2011;**121**:273–8
18 Lewis T, Levin M, Sommer DD. Too hot to handle--quantifying temperature variations in the nasal endoscope ocular assembly and light post. *Am J Rhinol Allergy* 2020;**34**:262–8
19 Ozturan O, Dogan R, Eren SB, Aksoy F. Intraoperative thermal safety of endoscopic ear surgery utilizing a holder. *Am J Otolaryngol* 2018;**39**:585–91