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Development of a Cost-Effective Surgical Headlight Using Consumer Light Emitting Diode Lighting and 3D Printing

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Abstract

Need. Battery-powered Light Emitting Diode (LED) surgical headlights are necessary for improved intraoperative illumination but may be costly. *Technical Solution.* The objective of this study was to develop a low-cost surgical headlight using a consumer-grade LED headlight and 3D-printed mount. *Proof of Concept.* Eighteen surgical residents performed simulation exercises that mimicked suturing in the oral cavity using both a custom prototype headlight and a commercial surgical headlight. The time required to complete the task with each headlight was recorded along with an exit survey. A second device was created based on the critiques of the first device and was tested by ten additional surgical trainees. Surgical residents completed the simulation task in 27 ± 8.6 seconds and 21 ± 5.6 seconds with the commercially available headlight and first prototype, respectively. In the second experiment, the simulation task was completed in 23 ± 11.1 and 23 ± 12.2 seconds with the commercially available headlight and second device, respectively. Survey results showed an overall positive consensus, with critiques about headband security, suggestions for smaller LED chassis, and a more robust mounting bracket. Some preferred the prototype headlight due to the wider field of illumination compared to the commercially available unit (ie, beam spread/beam angle). *Next Steps.* Future adjustments are required to optimize the location of the headlight and the battery to modify the weight distribution of the device. *Conclusion.* These findings demonstrate that our prototype models are viable alternatives to conventional surgical headlights and warrant continued optimization for broader adoption by surgeons and trainees for whom higher-cost alternatives are not an option.

Keywords

surgical simulation, cost-effective, surgical headlight, 3D printing

Need

A properly illuminated surgical field highlighting relevant anatomical structures is essential to producing optimal surgical results with most surgical disciplines using commercially available surgical headlights in addition to traditional operative lighting. Surgical headlights are used both for surgical procedures and simulations for education.[1] While the design of these surgical headlights vary substantially, most models include a bright collimated light source capable of bulk and fine-tune adjustment with multiple joints and share one common feature, significant expense ranging from $600 to over $6000. In addition, 80% of surgeons working in low- and middle-income countries identify poor lighting as a safety issue, and nearly 20% report direct experiences of poor-quality lighting leading to negative patient outcomes.[2] As such, there is an unmet clinical need for inexpensive surgical lighting.

Technical Solution

The emission spectra, specifically the visual acuity and color vision, of surgical headlights and general-purpose headlights do not differ significantly. Many recreational headlights use an elastic band with a single or no joint to rotate the light source, whereas surgical headlights often have a rigid headband for

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comfort or are mounted on glasses to minimize discomfort. Multiple joints or universal joints are often incorporated into surgical headlights to precisely direct light toward the target area and can be created with 3D printing.

Proof of Concept

The first surgical headlight prototype ($50.60) was created using headgear with a rigid headband (Pyramex HGBR Ridgeline Headgear with Ratchet & Pivoting Action, Black by Pyramex; Pyramex, Piperton, TN), a recreational headlight (Cobiz Headlight Flashlight, Cobiz, Seattle, WA), and 3D-printed joints (Formlabs Form 2 3D Printer; Formlabs Inc., MA) (Figure 1). Two 3D-printed (Formlabs, MA) joints were designed and printed using the SolidWorks software (Dassault Systems, Vélizy-Villacoublay, France) to connect the light and rigid head mount (Figure 2). The second headlight ($48.60) was built using a different recreational headlight (Cobiz Light Emitting Diode (LED) Headlight Flashlight-T6 Spot(Zoomable)+COB Board Flood Light, 10 hours Long Lasting, High Lumen Waterproof USB Rechargeable, Up-Close Work Head Light for Outdoor Camping Hunting; Cobiz, Seattle, WA) and a new design for the 3D-printed joints to decrease the overall weight.

We developed a simulation exercise to assess the functionality and ease of use between a commercially available surgical headlight (Surgitel Micro LED Headlight; Surgitel®, MI) and the prototype headlights. A low-cost simulation task recreated the psychomotor skills required to hand-tie surgical knots within the oropharynx. Seventeen orthopedic surgery residents and 1 otolaryngology resident completed the simulation with the first device and ten otolaryngology residents with the second device (Figure 3). The residents were timed and asked to complete a satisfaction survey with regard to each headlight. Student's t-test was performed to determine if there was a statistically significant difference between the 2 groups.

Figure 1. Materials for construction of the prototype headlights: (A) rigid headband; (B) commercially available recreational headlight for the first device; (C) commercially available recreational headlight for the second device; (D) 3D printer; (E) adhesive glue; (F) commercially available Velcro; (G) nut and bolt; (H) joint attached for headlight in the first device; (I) joint attached to the rigid headband in the first prototype; (J) joint attached to the headlight in the second prototype; and (K) joint attached to the rigid headband in the second prototype.

Results

Surgical residents completed the first simulation task in 21 ± 5.6 seconds using the first prototype headlamp compared to 27 ± 8.6 seconds with the commercially available headlight. This time difference between the groups was not only statistically significant ($P = .005$) but also clinically meaningful as the results from the survey detail in Table 1.

Surgical residents completed the second simulation using the second prototype in a comparable time to the commercially available headlight as trainees required 23 ± 12.2 seconds compared to 23 ± 11.1 seconds with the commercially available headlight, that is, a difference that was not statistically significant ($P = .446$). The results from the survey shown in Table 2 detailed that user satisfaction was highest with this second prototype with several commenting that they preferred this device over the commercially available headlamp.

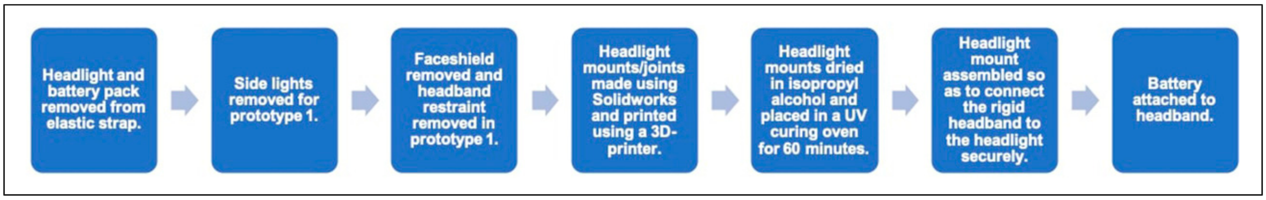

Figure 2. Flowchart of device development.

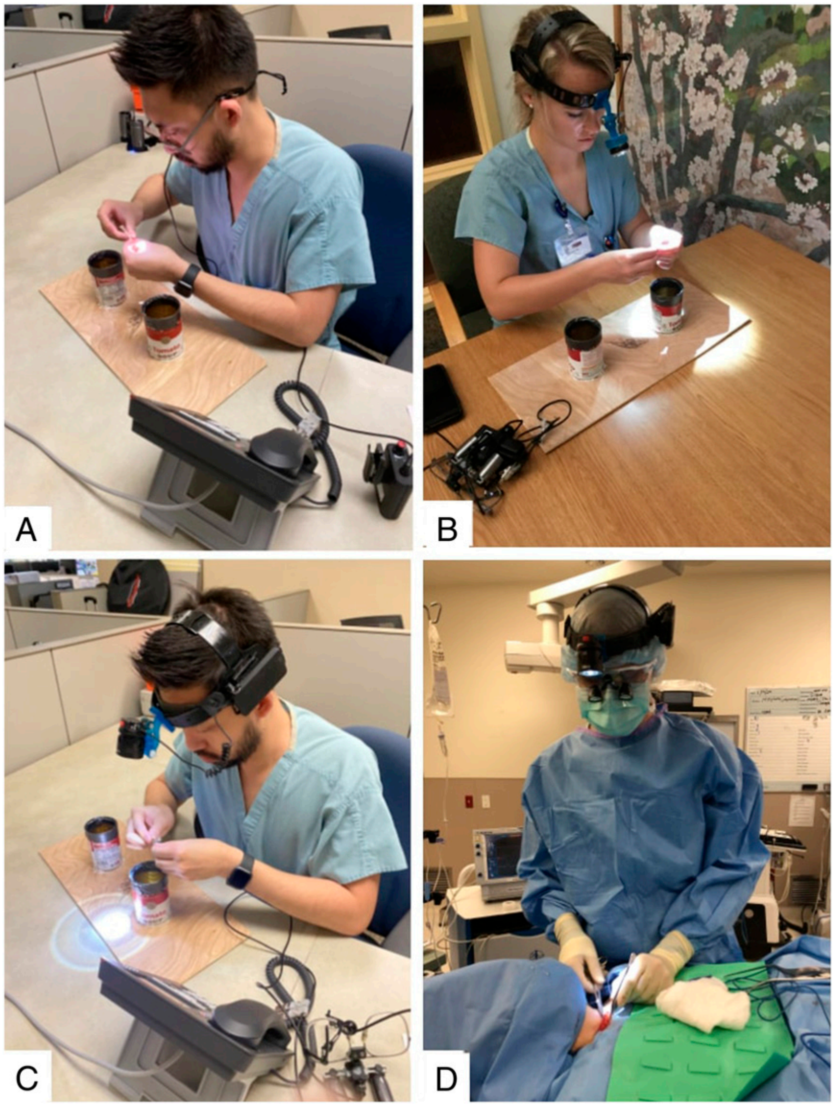

Figure 3. Images of surgical residents testing the headlights: (A) resident with the Surgitel Micro Light Emitting Diode headlight using the surgical simulation; (B) resident with the first headlight using the surgical simulation; (C) resident with the second headlight; and (D) resident using the second device in surgical procedures.

Table 1. Results of the Survey from the First Testing on July 11, 2019.

Question	Average	Standard Deviation
I can comfortably work with the headlight on	4.9	.32
The headlight was at a good temperature. (Did it overheat?)	5	.24
The focus area was large enough to work with	4.9	.32
The headlight produced a bright enough light to work with	4.9	.32
The headlight strap felt secure	4.3	.91
The headlight was not too heavy	4.7	.46
I was satisfied with the overall capabilities of the headlight	5	0
I prefer this model to my current headlight	5	0
I would consider using this model instead of my current headlight in the workplace	4.9	.24

Table 2. Results of the Survey from the Second Testing January 2, 2020.

Question	Average	Standard Deviation
I can comfortably work with the headlight on	4.6	.67
The headlight was at a good temperature. (Did it overheat?)	4.8	.46
The focus area was large enough to work with	4.6	.52
The headlight produced a bright enough light to work with	4.5	.71
The headlight strap felt secure	4.6	.69
The headlight was not too heavy	4.1	1.3
I was satisfied with the overall capabilities of the headlight	4.4	.84
I prefer this model to my current headlight	3.6	.98
I would consider using this model instead of my current headlight in the workplace	3.8	.71

Next Steps

Given that the alternative surgical headlights produced by this study had a significantly lower cost while maintaining comparable features of a more expensive commercial-grade surgical headlight, the prototypes demonstrated cost-effective quality and clinical equivalency during the surgical simulation task. Whereas many surgical headlights are attached to glass frames or loupes which force the weight of the headlight to the front, the light in our proposed devices stems from a rigid headband, keeping the center of gravity of the headlight closer to the user's head, and needs to be further optimized. Future adjustments are also underway to place the battery pack along the waist using a belt clip to minimize head-bearing weight.

Conclusion

By lowering the cost barrier to these devices integral to operative work, these models expand the access of headlights to surgical trainees or physicians in low-resource settings. The production of these headlights warrants continued optimization for broader adoption by residents and medical students for whom higher-cost alternatives are not an option.

Authors' Note

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Author Contributions

Study concept and design: Deven K. Gupta, Lily Chen, Andrew E. Heidari, and Brian J.-F. Wong
Acquisition of data: Deven K. Gupta, Steven Chau, and Brandyn Dunn
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Study supervision: Brian J.-F. Wong

Declaration of Conflicting Interests

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