


Novel Telemedicine Device for Diagnosis of Corneal Abrasions and Ulcers in Resource-Poor Settings

Corneal ulcers are a significant cause of corneal blindness worldwide.1 Normally, traumatic corneal damage and secondary infections are diagnosed by an ophthalmologist via slitlamp examination. However, limited health care resources in developing regions may delay diagnosis and treatment, increasing the risk of vision loss.2 Mobile phones are widely available even in resource-limited settings and therefore could potentially be used to aid in diagnosis of corneal pathology.3 Herein, we describe and test a custom-made smartphone attachment that allows diagnosis of corneal epithelial defects with a smartphone.

Methods | We designed a smartphone attachment to provide magnified images of the cornea with controlled illumination. The attachment consisted of a +25-diopter lens and external light-emitting diode (LED) light sources that were aligned with the smartphone camera for image acquisition (Figure 1). In one configuration, white LEDs (correlated color temperature of a 5250-K lamp) were used to capture white-light corneal photographs. In a second configuration, blue LEDs (472-nm peak wavelength) were used with a 550-nm/50-nm emission filter to capture fluorescein-stained corneal photographs. The attachments, which we refer to as Corneal CellScopes, slide on and off unmodified smartphones, allowing a single smartphone to take both white-light and fluorescein photographs.

To validate the smartphone attachments, we used an iPhone 4S (Apple Inc) to photograph 17 eyes from 17 patients at Chiang Mai University Hospital, Chiang Mai, Thailand. Participants had a slitlamp examination by an ophthalmologist, followed by photography with the white-light smartphone attachment. Fluorescein was then administered, followed by slitlamp examination and photography with the fluorescein smartphone attachment. Three off-site ophthalmologists graded all 34 photographs masked to the diagnosis, first as 34 independent photographs and then as 17 pairs of white-light and fluorescein photographs from the same eye. We calculated the agreement between the various assessments of an epithelial defect with Cohen κ. We estimated the sensitivity and specificity of smartphone photography versus the on-site ophthalmologist using the grades of all 3 graders and constructed 95% confidence intervals by percentile bootstrap, resampling eyes to account for nonindependence between grades of the same eye (10 000 repetitions). Analyses were performed with Stata version 12.0 statistical software (StataCorp LP). Institutional review board approval was obtained from the University of California, San Francisco. Written informed consent was obtained from all participants.

Results | The on-site ophthalmologist detected an epithelial defect in 6 of 17 eyes (Figure 2 and eFigure in the Supplement). The consensus diagnosis (agreement of ≥2 of the 3 graders) detected an epithelial defect in 5 eyes—all of which also had an epithelial defect diagnosed by the on-site ophthalmologist. Agreement between the 3 graders for the diagnosis of epithelial defect was good (κ = 0.73; 95% CI, 0.53–0.91). Agreement between the consensus diagnosis and the on-site ophthalmologist’s diagnosis for epithelial defect was excellent (κ = 0.87; 95% CI, 0.61–1.00). Compared with the on-site ophthalmologist’s examination, the sensitivity of photographic diagnosis of an epithelial defect was 83.3% (95% CI, 61.1%–100%) and specificity was 97.0% (95% CI, 90.9%–100%). When the white-light and fluorescein photographs were assessed as a pair, the sensitivity of photographic diagnosis of an epithelial defect improved to 88.9%
(95% CI, 66.7%-100%), while the specificity decreased to 90.9% (95% CI, 78.8%-100%).

Discussion | Developing regions of the world are highly burdened by corneal ulcers that ultimately lead to corneal blindness. As wireless telecommunication coverage continues to expand in regions with limited health care resources, low-cost, easy-to-use smartphone devices may be substituted for expensive and highly technical medical instruments used to diagnose corneal ulcers. In this article, we demonstrated that smartphone attachments capturing white-light and fluorescein photographs show potential as a new technology for the diagnosis of corneal trauma in resource-poor settings.

Robi N. Maamari, MD
Somsanguan Ausayakhun, MD
Todd P. Margolis, MD, PhD
Daniel A. Fletcher, PhD
Jeremy D. Keenan, MD, MPH

Author Affiliations: Francis I. Proctor Foundation and Department of Ophthalmology, University of California, San Francisco (Maamari, Margolis, Keenan); Department of Ophthalmology, Faculty of Medicine, Chiang Mai University, Chiang Mai, Thailand (Ausayakhun); Department of Bioengineering and Biophysics Program, University of California, Berkeley (Fletcher).

Corresponding Author: Robi N. Maamari, MD, Francis I. Proctor Foundation, 95 Kirkham St, San Francisco, CA 94143 (rmaamari@uci.edu).

Author Contributions: Dr Keenan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Maamari, Margolis, Fletcher, Keenan.

Acquisition, analysis, or interpretation of data: Maamari, Ausayakhun, Margolis.

Drafting of the manuscript: Maamari, Ausayakhun.

Critical revision of the manuscript for important intellectual content: Maamari, Margolis, Fletcher, Keenan.

Statistical analysis: Maamari, Keenan.

Obtained funding: Maamari, Margolis.

Administrative, technical, or material support: Maamari, Ausayakhun, Fletcher.

Study supervision: Margolis, Fletcher.

Conflict of Interest Disclosures: Drs Maamari, Margolis, and Fletcher have pending intellectual property with the University of California describing a mobile phone camera for retinal imaging. At this time, this intellectual property has no financial value. Dr Margolis reports having received a grant from That Man May See during the conduct of the study. Dr Fletcher is a cofounder of CellScope Inc, which is a medical device start-up company using mobile phones for disease screening and diagnosis. CellScope Inc was not involved in this research.

Funding/Support: This work was supported by a Medical Student Eye Research Fellowship Grant from Research to Prevent Blindness (Dr Maamari), the University of California, Berkeley Blum Center for Developing Economies (Dr Fletcher), and grant K23 EYO10971 from the National Eye Institute.

Role of the Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Previous Presentation: An abstract with preliminary findings of this study was presented at the 2013 Annual Meeting of the Association for Research in Vision and Ophthalmology; May 7, 2013; Seattle, Washington.


