ORIGINAL ARTICLE: ANDROLOGY

# Novel device for male infertility screening with single-ball lens microscope and smartphone

Yoshitomo Kobori, M.D.,[a,b] Peter Pfanner, B.App.Sc., M.D.M.,[b] Gail S. Prins, Ph.D.,[b] and Craig Niederberger, M.D.[b]

[a] Department of Urology, Dokkyo Medical University Koshigaya Hospital, Koshigaya, Japan; and [b] Department of Urology, University of Illinois at Chicago, Chicago, Illinois

**Objective:** To investigate the usefulness of a novel semen analysis device consisting of a single-ball lens microscope paired with a state-of-the-art smartphone equipped with a camera.
**Design:** Laboratory investigation.
**Setting:** University research laboratory.
**Patient(s):** A total of 50 semen samples obtained from volunteers were analyzed for count, concentration, and motility with an 0.8-mm ball lens and three types of smartphone. Comparisons were made with results obtained with a laboratory-based computer-assisted sperm analysis (CASA) system.
**Intervention(s):** None.
**Main Outcome Measure(s):** Sperm concentration; sperm motility.
**Result(s):** Sperm concentration counted with a ball lens and each smartphone showed a very strong correlation with the CASA results. Likewise, sperm motility calculated with our device showed significant correlations to CASA. If eight spermatozoa or fewer were found on the field of view of an iPhone 6s, the semen specimens were considered to be below the lower reference limit for sperm concentration of World Health Organization 2010 guidelines ($15 \times 10^6$ spermatozoa/mL). The sensitivity was 87.5%, and specificity was 90.9%.
**Conclusion(s):** Smartphones have great potential to analyze semen because they are portable, contain excellent digital cameras, and can be easily attached to a microscope. A single-ball lens microscope is inexpensive and easy to use for acquiring digital microscopic movies. Given its small size and weight, the device can support testing for male fertility at home or in the field, making it much more convenient and economical than current practice. This single-ball lens microscope provides an easy solution for global users to rapidly screen for male infertility. (Fertil Steril® 2016;■:■–■. ©2016 by American Society for Reproductive Medicine.)
**Key Words:** Infertility, semen analysis, sperm concentration, sperm motility

**Discuss:** You can discuss this article with its authors and with other ASRM members at http://fertstertforum.com/koboriy-smartphone-semen-analysis/

Worldwide reports suggest that infertility affects 15%–20% of couples of reproductive age, and approximately 50% of these are accountable to the male partner (1). Although men with infertility represent a significant percentage of the infertile population, public awareness of this fact is limited at best. Literature and the other media have often neglected the male component of reproduction other than its sexual nature (2). Wider access to male infertility assessment may help to resolve this deficiency.

Semen analysis is the key element in diagnosing the reproductive potential of a man with fertility in question. In current practice men must use a clinic or other hospital facility to have their semen analyzed. Once at the clinic, they are asked to produce a semen sample, which is then analyzed by staff at the clinic. Many subjects are not comfortable with this procedure, which they often find embarrassing and expensive (3).

A Dutch scientist, Antonie van Leeuwenhoek, first discovered the spermatozoon in 1677 using a single-ball lens microscope that he had invented. He is considered to be "the father of optic microscopy" and bacteriology (4). He constructed a magnificent ball lens microscope with which he was able to observe very tiny objects in detail. He became the first to observe protozoa, red blood cells, the sperm of animals, and bacteria (5). The development and deployment of ball lenses have recently indicated their usefulness in a number of medical areas (6). Here

Received February 29, 2016; revised May 2, 2016; accepted May 31, 2016.
Reprint requests: Yoshitomo Kobori, M.D., Department of Urology, Dokkyo Medical University Koshigaya Hospital, 2-1-50 Minamikoshigaya, Koshigaya, Japan 343-8555 (E-mail: ykobori@dokkyomed.ac.jp).

Fertility and Sterility® Vol. ■, No. ■, ■ 2016 0015-0282/$36.00

http://dx.doi.org/10.1016/j.fertnstert.2016.05.027

we report on a novel semen analysis device consisting of a van Leeuwenhoek's single-ball lens microscope paired with a state-of-the-art smart phone equipped with a camera of the kind found in nearly all commercial smart phones.

## MATERIALS AND METHODS

### Ball Lens Microscope

We developed a Leeuwenhoek's microscope constructed with a single-ball lens of 0.8 mm in diameter (Hirosofu Japan) inserted into a plastic jacket that attaches to a commercial smart phone. For a ball lens, basic measures of optical performance can be described in terms of the ball radius (r), index of refraction (n), effective focal length (EFL), and magnification (MAG). As the distance of distinct vision is 250 mm, for an 0.8-mm diameter ball lens:

$$\mathrm{EFL} = n \times r/2(n-1) \simeq 0.45$$

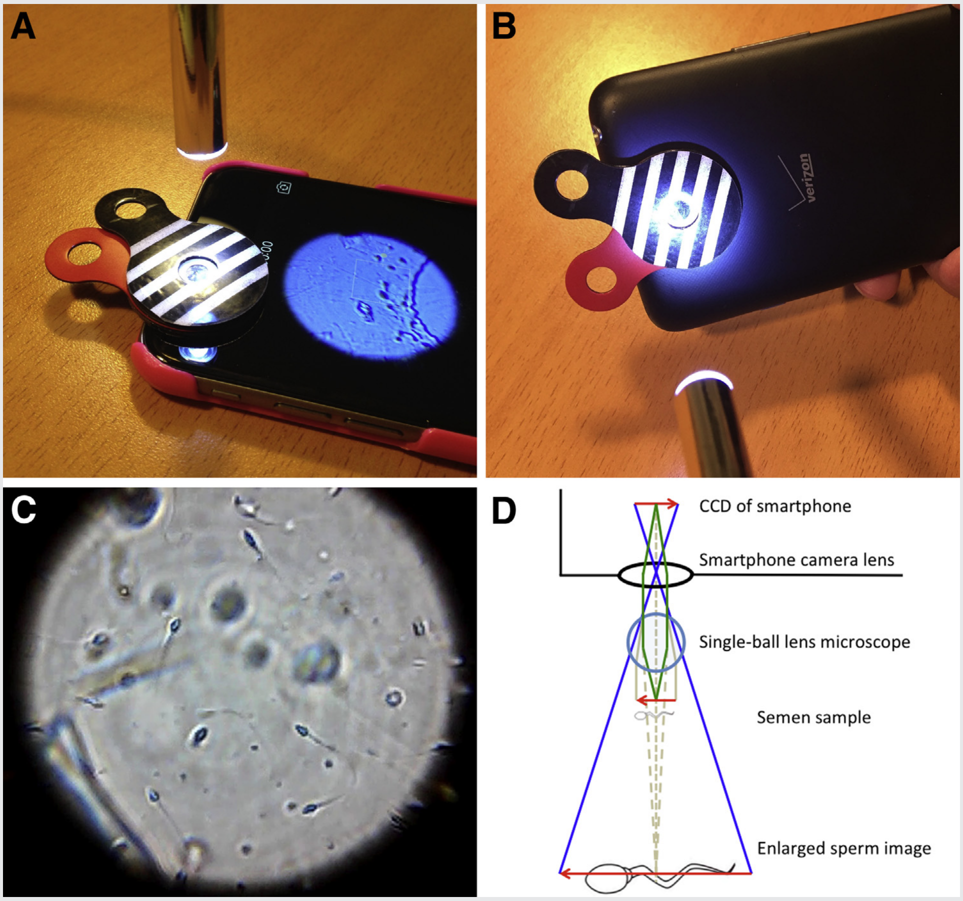
$$\mathrm{MAG} = 250/\mathrm{EFL} \simeq 555$$

The approximate magnification provided by this ball lens was 555 times. As the ball lens becomes smaller, the magnification becomes lager. We chose the 0.8-mm ball lens because this magnification was adequate to see sperm size. This method uses ambient illumination as its light source and does not require the incorporation of a dedicated light source. In this study, semen samples were backlit by a small single light-emitting diode flashlight. An image of sperm that had been enlarged by a single-ball lens was photographed in the smartphone camera. The picture was recorded for 3 seconds by the charge-coupled device image sensor of a smartphone camera.

### Smartphone Camera

Three types of smartphones were used in this study: iPhone 5s (iOS 8, 8-megapixel [MP] camera, 1080p high-definition [HD] video, 30 frames per second; Apple), iPhone 6s (iOS 9, 12-MP camera, 1080p HD video, 60 frames per second; Apple), and LG Optimus Exceed2 (Android 4.4, 5 MP, 800 × 480 of video resolution). When the iPhone 5s and iPhone 6s were used, a

FIGURE 1




(**A**) The mobile phone microscopy apparatus with an 0.8-mm ball lens enveloped in a plastic jacket and attached to the iPhone 6s FaceTime camera. (**B**) The technique for observing semen sample using a ball lens and LG Optimus Exceed 2 with a single light-emitting diode flashlight providing illumination. (**C**) The sperm could be observed clearly with a ball lens and iPhone 5s. (**D**) Diagram of this ball lens and smartphone camera.

*Kobori. Smartphone semen analysis. Fertil Steril 2016.*