Research Article

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Measurement of Corneal Diameter Using Smart Phone Technology

Mosa Al Harby[1]*, Mohammed Al Shamrani[1] and Deepak P Edward[1,2]

[1]*King Khaled Eye Specialist Hospital Eye Specialist Hospital Riyadh, Saudi Arabia*

[2]*Wilmer Eye Institute, Johns Hopkins University, Baltimore, Maryland, USA*

*Corresponding author: Mosa Al Harby, MD. King Khaled Eye Specialist Hospital, PO box 719, Al Aroubah Road, Riyadh, Saudi Arabia, Tel: +966 114821234 ext. 3773; Email: mharby@kkesh.med.sa

Abstract

Purpose: To compare horizontal white-to-white (WTW) corneal diameter measurements in children with the MultiMeasureTM iPhone application versus a caliper and evaluate the repeatability of MultiMeasureTM.

Methods: This prospective, comparative pilot study enrolled 20 children. The horizontal WTW diameter was measured with calipers with the patient in primary gaze (caliper group). Subsequently, corneal photography was performed with the iPhone in primary gaze (primary group) and with a 20° head turn (HT group). MultiMeasureTM was used to measure WTW. To evaluate repeatability of MultiMeasureTM, WTW was measured in 15 children from a clinic while awake (repeatability group) in primary gaze and with a 20° head turn. Three measurements were performed for all patients. Statistical significance was indicated by p<0.05.

Results: The mean age of the sedated patients was 8.3 years (range, 2 to 15 years). The mean WTW was 11.68 ± 0.41 mm, 11.85 ± 0.28 mm and 11.34 ± 0.47 mm in the caliper, primary and HT groups respectively. There was a statistically significant difference between measurements in the caliper and HT groups only (p=0.006). Inter-test variability was not statistically significant different (p=0.45 primary group, p=0.37 HT group, p=0.37 caliper group). The mean age of 15 patients in the repeatability group was 7.6 years (range, 3 to 15 years). In the repeatability group, there was a statistically significant mean difference of 0.36 mm between the repeatability group in primary gaze versus head turned (p=0.001).

Conclusion: The smart phone application was a fast, convenient, non-contact, repeatable method for measuring the corneal diameter in children in primary gaze.

Keywords: White to white; Caliber; Smartphone technology; Children

Introduction

Corneal diameter measurement is essential in children suspected with congenital glaucoma or in the presence of other congenital corneal anomalies [1,2]. The corneal diameter is typically measured with a contact caliper which requires topical anesthesia, sedation or general anesthesia. However, an easier, more efficient method would be a non-contact measurement of corneal diameter without requiring sedation, topical or general anesthesia. Corneal photography has been used to measure corneal diameter noninvasively [3-5]. Although photography is a non-contact method, a number of steps are involved that preclude application in routine clinical practice. Smart phones have incorporated excellent photography and zoom functions that could have clinical applications. Additionally, smart phones are ubiquitous, relatively inexpensive and easily portable.

Recently new software applications are available for some smartphones that serve as digital measurement tools that can measure point-to-point distances within a millimeter of accuracy. However literatures on the use of these software applications for ocular measurements are not available in the peer reviewed literature. In this study we compare corneal diameter measurement in children with a smart phone device and a commercially available software application

to standard caliper measurements. We also evaluate the repeatability of measurements of the software application and the effect of corneal diameter measurement based on head position.

Methods

This study was designed to address two objectives. The first objective was to compare horizontal white-to-white (WTW) corneal diameters in sedated children in primary gaze and head turned position using the Multi-MeasureTM software application (www.MoPlease.com) to standard caliper measurements. The second objective was to measure the repeatability of WTW measurements using the iPhone (Apple Inc, Cupertino, California USA) application in children who were awake. The study was approved by the institutional ethics committee at the King Khaled Eye Specialist Hospital, Riyadh, Saudi Arabia. This study adhered to the tenets of the Declaration of Helsinki.

For the first objective, 20 patients scheduled for general anesthesia for non-corneal surgeries were recruited with parental consent. The WTW horizontal corneal diameter was measured in primary gaze with calipers after calibrating it to standard ruler in each case by one observer (caliper group). This was followed by corneal photography by a second observer with the iPhone application with a standard calibrating ruler placed at the lateral orbital margin. The photography was performed at 50 cm from the patient in primary gaze (primary

group) and with a 20° head turn (HT group). The Multi-Measure™ application was then used to measure horizontal corneal diameter as described below. Three successive measurements were performed in the three study groups. To eliminate bias, a second investigator calculated horizontal corneal diameter using the iPhone application. The intra-and inter-tests variability in the measurements were compared between the caliper method and the MultiMeasure™ application. Additionally, WTW measurements were compared for the primary group and the HT group.

To measure the repeatability of the iPhone software application, 15 patients were recruited (repeatability group) from the pediatric ophthalmology clinic. The corneal diameter was measured in primary gaze and with a head turn of approximately 20° in children who were awake and had not received sedation, topical or general anesthetic. The measurements were performed at approximately 50 cm from the patient. A ruler was place vertically at the lateral orbital margin. Three measurements were performed in both positions. To eliminate bias, a second investigator calculated horizontal corneal diameter using the iPhone software application. Inter-test variability was compared and the WTW measurements were compared in primary gaze and head turn positions. No caliper measurements were performed in the repeatability group.

Corneal Diameter Measurement Using the MultiMeasure™ Software Application and the iPhone

The iPhone model 4 with the iOS4 operating system was used for this study (Figure 1). MultiMeasure™ version 2.0.3 (30) downloaded from the Apple iTunes Store was the digital measurement software application. To function correctly, this application required an operating system version 4.3 or later. The software is compatible with iPhone, iPod touch and iPad but is currently unavailable for Android phones.
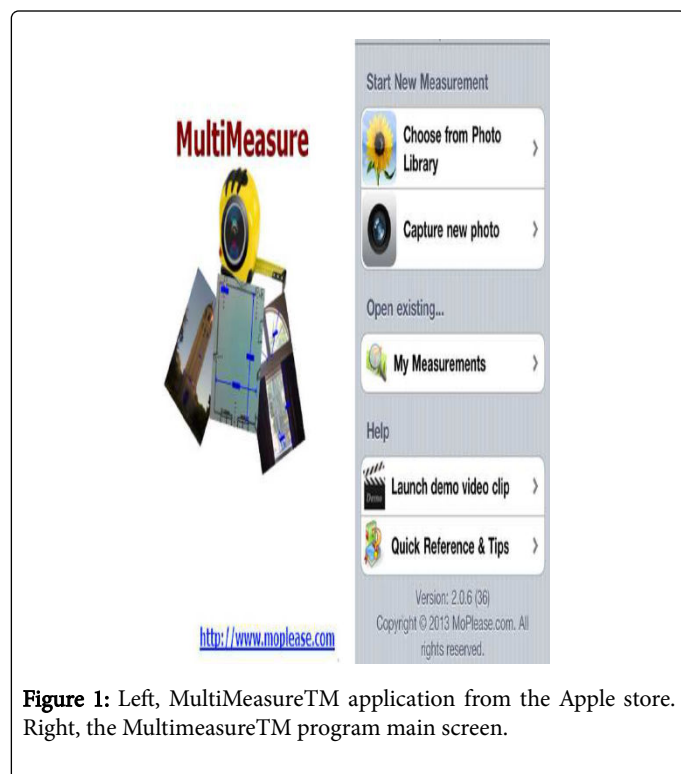

Figure 1: Left, MultiMeasure™ application from the Apple store. Right, the Multimeasure™ program main screen.

The following steps were used to perform the measurement:

The technique is illustrated in figures 2 and 3 following alignment of a standard ruler with the lateral orbital margin:

1. Photograph the face at 40 to 50 cm distance using the iPhone camera which does not have to be in the zoom mode (Figure 2).
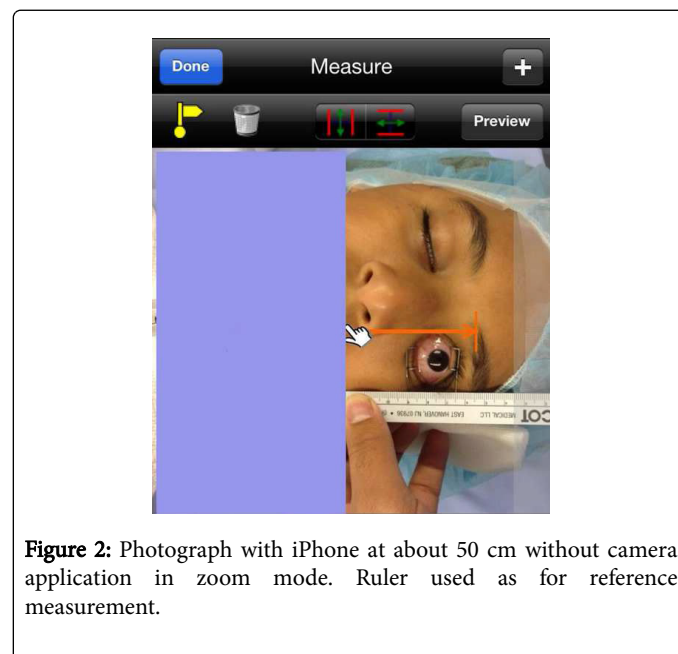

Figure 2: Photograph with iPhone at about 50 cm without camera application in zoom mode. Ruler used as for reference measurement.
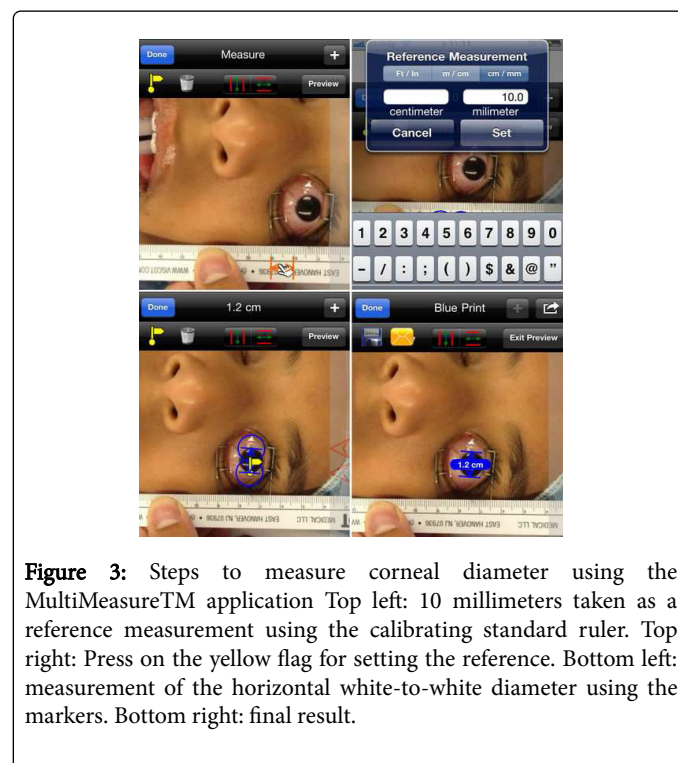

Figure 3: Steps to measure corneal diameter using the MultiMeasure™ application Top left: 10 millimeters taken as a reference measurement using the calibrating standard ruler. Top right: Press on the yellow flag for setting the reference. Bottom left: measurement of the horizontal white-to-white diameter using the markers. Bottom right: final result.

2. Zoom in on the cornea using the iPhone application once the photograph is obtained (Figure 3a).

3. Open the photograph in the MultiMeasure™ application and calibrate the markers using the standard ruler. Following calibration,

the markers were aligned to measure the WTW corneal diameter using the measurement application without a personal computer (Figures 3b-3d).

Statistical analysis was performed with the paired t-test and Friedman test to detect differences across multiple test attempts .The mean WTW of all groups were compared to each other. A p value less than 0.05 was considered statistically significant.

Results

The mean age of the study group was 8.3 years (range, 2 years to 15 years) for the comparison between measurements from the iPhone and the caliper. The mean WTW was 11.68 ± 0.4 1 mm in the caliper group. The mean WTW was 11.85 ± 0.28 mm in the primary group and 11.34 ± 0.47 mm for the HT group. The measurements between the caliper group and the primary group were not statistically different (p=0.098). The difference in measurements between the caliper group and the HT group were statistically significant (p=0.006). The inter-test variability was not statistically significant in all three groups (p=0.45 primary group; p=0.374 HT group; p=0.37 caliper group: Friedman test).

The mean age for the repeatability group was 7.6 years (range, 3 years to 15 years). The mean WTW with MultiMeasure^{TM} in primary gaze was 12.3 ± 0.62 mm and 11.9 ± 0.63 mm with a head turn. There was a statistically significant difference of 0.36 mm between the MultiMeasure^{TM} WTW measurements in the head turn position and in primary gaze for the repeatability group (p=0.001). There was no statistically significant difference in inter-test variability in the successive measurements in both groups (p=1.0 primary gaze; p=0.89 head turn group: Friedman test).

Discussion

An enlarged corneal diameter is a strong indicator of pediatric glaucoma [1]. Conversely, a small corneal diameter may indicate microphthalmos or microcornea, with important implications for vision and associated ocular pathology [2]. An accurate and reliable noncontact method without the use of anesthetics to measure corneal diameter would be useful in the pediatric population and children. To our knowledge there are four studies in the literature that have investigated corneal diameter using various photographic methods. Aizawa and colleagues used a fixed focus camera and measured the corneal diameters in 40 children (up to 6 years) but did not directly compare their results with values from a caliper [5]. Robinson and colleagues used a Medical-Nikkor f200 mm lens attached to a Nikon F1 camera with a fast film and measured the corneal diameter in pediatric and adult patients [6]. The method required additional steps such as film processing and using a magnifying scale lens. Lagrèze and colleagues studied 92 patients by photographing the eye of interest twice with a Nikon Coolpix 4500 digital camera and a paper ruler taped on the forehead above the eyebrows or with a plastic ruler held in that position [3]. Thereafter, the images were copied to a desktop personal computer, opened with standard imaging software and processed and cut and final measurement of the corneal diameter computed. One drawback of this study was that the ruler tape was placed on forehead and not on the plane of the eye for comparative validation. The ruler provides a standardized measurement scale that, when placed in the corneal plane, minimizes parallax errors that would lead to over- or under- estimation of measurements. Puvanachandra et al. used a digital camera and measured the horizontal corneal diameter in 40 eyes while the ruler was held vertically at the lateral orbital margin in the plane of the eye [4]. The photograph was then magnified on the LCD screen by using the camera's image zoom function and the corneal diameter measured once the size of the ruler image reached the size of the real ruler. The drawbacks of the studies summarize above are the additional steps, equipment and the added cost to obtain the final corneal diameter. Additionally, the inefficiency of these photographic methods does not lend itself to clinical practice. In order to increase efficiency of the previously documented photographic methods, additional personnel may be required or personnel may need to be retasked for this specific purpose, each incurring additional cost.

The use of an iPhone to obtain corneal diameter measurements (WTW) has several advantages. Firstly, it does not require additional instrumentation or processing and take approximately 2-3 minutes to obtain the measurement and process the image. Secondly there is no training involved and any clinic personnel can perform this task. Lastly, smart phones are available and frequently used by physicians [7]. Most smart phones have an excellent photographic capability with zoom options. Recently, new applications are available which serve as measurement devices and can measure point-to-point distances within millimeters of accuracy. In this study we used an example of one such digital application, the Multimeasure^{TM} application.

In the current study we were able to measure corneal diameter under various clinical settings. In the sedated patient, corneal diameter measurements were comparable to measurement with a standard caliper. Additionally, inter-test variability measurements showed that the iPhone measurements were reliable in both sedated and awake patients. The same rigor for testing measurements was not available when photographic methods were used to measure corneal diameter noninvasively. Hence there is no data from the literature for comparative purposes. However, in the head turn position, corneal diameters were statistically significantly different from primary gaze readings. We believe that this testing was important since in an awake child as head movement during photography might result in slight head tilt. We noted that corneal diameter with the head turned 20° was smaller than when measured with the patient in primary gaze in both sedated patients and patients who were awake. In the head turned position, a slight blurring of photograph makes it difficult to accurately place the markers and could be the source of this difference. Another potential source of error in measurements could be the increments at which the Multimeasure^{TM} application is scaled. Currently measurements are made at increments of 1 mm and therefore changes less than 0.5 mm are not possible. This may limit the precision of the measurement. However, caliper measurements also provide measurements with 1 mm increments. Future refinement of measurement technology using smart phone applications might be available in 0.1 mm increments and will make digital measurement technology more precise.

In summary, we believe that the method of smart phone coupled with a software application such as the Multimeasure^{TM} is a fast, convenient, non-threatening, and repeatable method for measuring the corneal diameter in children in primary gaze. We believe that this method can be used in a busy clinic in patients who are awake where measurements can be made without patient contact or exposure to sedation or general anesthesia or topical anesthetic. In addition this application could be potentially applied to measure the palpebral fissure and pupil size. Further enhancement and development of such programs are needed to increase the accuracy of the technology even in uncooperative candidates.

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