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Repeatability of infrared ocular thermography in assessing healthy and dry eyes

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ABSTRACT

Purpose: To investigate the inter-image, inter-occasion and inter-examiner repeatability of NEC infrared thermo-tracer TH 9260 in assessing healthy and dry eyes.
Methods: Ocular surface temperature (OST) was recorded using NEC infrared thermo-tracer TH 9260 on 21 healthy and 15 dry eyes. Data from the right eyes were analyzed. Marking of the ocular surface and OST acquisition was performed using a new 'diamond' demarcation method. Twelve OST indices were obtained at three different time points following a blink: 0 s, 5 s and 10 s. Inter-image, inter-occasion and inter-examiner repeatability of the infrared ocular thermography was evaluated by calculating coefficients of repeatability (COR).
Results: Ten out of the twelve tested OST indices had good repeatability with small inter-image variability (%COR: 0.2–0.9), inter-occasion variability (%COR: 2.1–3.7) and inter-examiner variability (%COR: 1.5–3.7) for the three studied time points. Two of the OST indices (temperature standard deviation of the region of interest and radial temperature difference) had poor repeatability with much larger inter-image variability (%COR: 8.9–140.7), inter-occasion variability (%COR: 47.5–153.5) and inter-examiner variability (%COR: 54.7–142.0) for the three studied time points.
Conclusions: Most of the metrics adopted in this assessment can be considered to be highly repeatable.

1. Introduction

Infrared (IR) ocular thermography determines ocular surface temperature (OST) of the eye and pre-orbital skin by measuring the amount of IR radiation emitted from the surface with an infrared thermal imaging camera. Measurements are then processed into a color-coded display image for interpretation and analysis [1]. Non-invasive ocular thermography was first introduced in 1968 and was used to evaluate both normal and pathological conditions [2–5] and later for dry eye [1,6]. It has the advantages over a contact device of being non-invasive, rapid and without the risk of trauma and contamination [5].

The methods used in ocular surface marking and OST acquisition reported in the literature have varied widely (Table 1) resulting in different OST indices studied. Although automated methods of OST acquisition have occasionally been adopted [7], a more manual approach has generally been employed [1,6–24] (Table 1).

The magnitude of repeatability is an important consideration for the clinical use of technical and other devices. While dynamic ocular thermography has been reported to have high accuracy and sensitivity [20], little has been reported about its repeatability. The current study was designed to evaluate the repeatability of NEC infrared thermo-tracer TH 9260 in assessing healthy and dry eyes in three different aspects: inter-image, inter-occasion and inter-examiner variability. A newly developed 'diamond' demarcation method was used to mark the ocular surface and study twelve OST indices. In common with all scientific evaluations, repeated measures of the 'diamond' method in marking the ocular surface and OST acquisition will necessarily varied due to factors such as instrument fluctuation or non-uniformity within or between samples [25]. Such variation is termed measurement error and can be reported by giving the coefficient of repeatability (COR), defined as the maximum difference likely to occur between two successive measurements [26].

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Table 1
Ocular surface marking and OST acquisition reported in the literature.

Authors	OST acquisition	Ocular surface marking method
Efron et al. [8]	Manual	11 points running across the anterior eye
Morgan PB [1], Morgan et al. [6], Morgan PB [9]	Manual	Five 10 × 10 boxes placed in five anatomical locations along horizontal meridian running across the estimated centre of the cornea
Galassi et al. [10]	Manual	Five points placed on centre of the cornea, internal and external canthi, half-way from the internal canthus and nasal limbus, half-way from the external canthus and temporal limbus
Sodi et al. [11]	Manual	Five points equally placed along a horizontal line running through centre of the cornea, connecting medial and lateral canthi
Murphy et al. [12]	Manual	A squared 10 × 10 pixels box placed at the centre of the cornea
Mori et al. [13]	Manual	A squared 20 × 20 pixels box placed at the centre of the cornea
Chiang et al. [14]	Manual	An enriched region of 4.4 mm diameter (22 pixels)
Ng et al. [15]	Manual	A small circle placed at the centre of the cornea
Cardona et al. [16]	Manual	A circular region placed at the centre of the cornea
Craig et al. [17]	Manual	Mean of central cornea pixels
Purslow et al. [18], Purslow and Wolffsohn [19]	Manual	23 points placed across the anterior eye
Tan et al. [20]	Manual	20 points placed across the anterior eye, lined up in the shape of "+"
Chang et al. [21]	Manual	Acquire local temperature of lateral orbit, upper eyelid, caruncle, medial conjunctiva, lateral conjunctiva, lower eyelid and cornea
Acharya et al. [22]	Semi-auto	Image was manually cropped to consist only of eye, the cornea was then detected by algorithm developed
Tan et al. [7]	Automated	The eye was localized by genetic snake algorithm, and the cornea diameter and location were derived from the resultant snake points
Kamao et al. [23]	Manual	Central corneal 4 mm in diameter, Conjunctiva temporal and Conjunctiva nasal (both 2 mm in diameter)
Su et al. [24]	Manual	ROI (region of interest) determined by four curves connected between four manually set apexes (top and bottom of the eye, left and right corner of the eye)

2. Methods

2.1. Subjects

The research protocol was approved by the Singapore National Health Group (NHG) Domain-Specific Review Board (DSRB) and the Singapore Polytechnic ethics review committee and the work adhered to the tenets of the Declaration of Helsinki. Twenty-one healthy (41 ± 9 years; 11 females, 10 males) and 15 dry eye (45 ± 10 years; 11 females, 4 males) subjects were recruited. Informed consent was obtained from each subject at study enrolment. The inclusion criteria for the dry eye subjects were: use of tear replacement therapy and had either a fluorescein tear break-up time of 10 s or less [36], or a Schirmer I test result of less than 10 mm in 5 min [6] along with presence of corneal or conjunctiva staining. A drop of fluorescein sodium HCL was instilled on the subject's eye and the cornea and tear film were assessed using cobalt blue light, viewed through a yellow barrier filter (Wratten #12) for fluorescein tear break-up time and corneal/conjunctival staining. All dry eye subjects were screened and

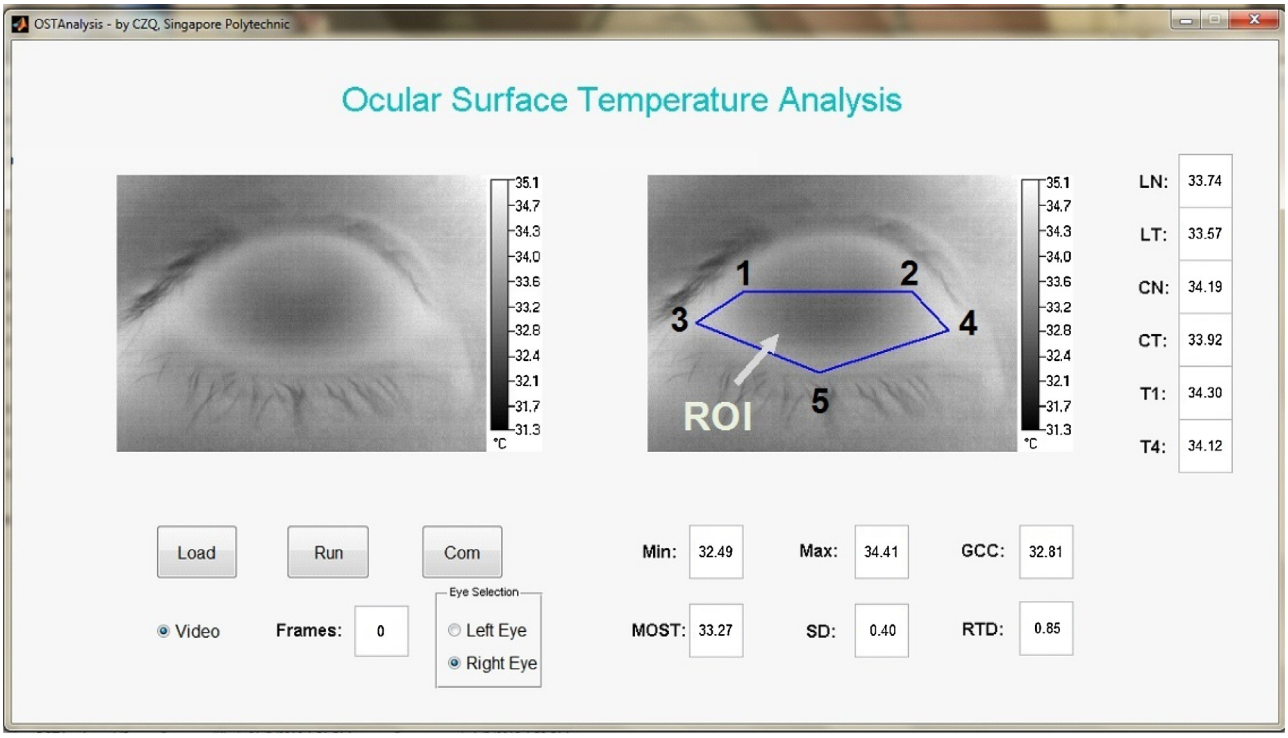

Fig. 1. Marking on ocular surface and OST acquisition using the 'diamond' method with the OST Analysis V2 software.