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Developments in contact lens measurement: A comparative study of industry standard geometric inspection and optical coherence tomography

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ABSTRACT

Purpose: The aim of this study was to compare a developmental optical coherence tomography (OCT) based contact lens inspection instrument to a widely used geometric inspection instrument (Optimec JCF), to establish the capability of a market focused OCT system.
Methods: Measurements of 27 soft spherical contact lenses were made using the Optimec JCF and a new OCT based instrument, the Optimec is830. Twelve of the lenses analysed were specially commissioned from a traditional hydrogel (Contamac GM Advance 49%) and 12 from a silicone hydrogel (Contamac Definitive 65), each set with a range of back optic zone radius (BOZR) and centre thickness (CT) values. Three commercial lenses were also measured; CooperVision MyDay (Stenfilcon A) in −10D, −3D and +6D powers. Two measurements of BOZR, CT and total diameter were made for each lens in temperature controlled saline on both instruments.
Results: The results showed that the is830 and JCF measurements were comparable, but that the is830 had a better repeatability coefficient for BOZR (0.065 mm compared to 0.151 mm) and CT (0.008 mm compared to 0.027 mm). Both instruments had similar results for total diameter (0.041 mm compared to 0.044 mm).
Conclusions: The OCT based instrument assessed in this study is able to match and improve on the JCF instrument for the measurement of total diameter, back optic zone radius and centre thickness for soft contact lenses in temperature controlled saline.

1. Introduction

With the increasing usage of contact lenses worldwide, the continual improvement of manufacturing methods and the increasing complexity of contact lens designs and materials, the inspection and quality control of contact lenses is paramount. Typically, inspection of contact lenses can be split into two broad areas: geometric inspection (e.g. curvature, centre thickness) and optical performance measurement (e.g. central and peripheral power). There are a wide range of methods available for geometric metrology, either included in the current ISO standards [1] (e.g. mechanical thickness gauges, optical projection techniques, ultrasound, v-gauges) or those more recently developed (e.g. low coherence interferometry [2], ptychography [3]). ISO standards are developed based on the available methods at the time of publication and as a result there are a number of potential shortcomings in the standard methods for contact lens inspection. Centre thickness measurement is conducted in air, resulting in a lack of appropriate temperature and hydration control, factors which can cause significant lens shape changes [4]; multiple instruments generally need to be utilised to obtain all the required measurements of a lens (e.g. measurement of sagittal depth [5], obtaining both centre thickness and curvature); there may be a large level of subjectivity in the measurements due to the usage of analogue measurement methods, and the time taken for measurement can be significant.

More importantly these methodologies only cover a small number of the wide range of clinically important parameters that are part of soft contact lens design and manufacture, with the

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standards principally covering centre thickness, posterior curvature (typically referred to base curvature or back optic zone radius, BOZR) and diameter. In particular, there is currently no standard for measuring key dimensional parameters at positions other than the centre of a lens, with emerging research showing the importance of measuring both sagittal depth [5] and thickness [6] at these positions, with peripheral shape becoming increasingly important for emerging lens designs such as those for myopia control [7]. As a result, there is an increasing need for instrumentation that can offer measurement of the key parameters across the entire lens, for all different lens designs and materials, with appropriate temperature control of the measurement medium.

One approach that may offer this functionality is optical coherence tomography (OCT), which has already been shown to be effective in measuring soft and rigid lenses [8–11]. To date, the application of OCT to contact lenses has utilised high-specification and therefore high-cost OCT systems. In addition these studies utilise methods that are impractical for usage in production, such as contrast enhancing agents in the measurement medium [8,11] or complex lens positioning methods [11]. The purpose of the current study is to compare the measurement capability of an industry focused OCT contact lens instrument, with a standard geometric inspection instrument that is widely used in contact lens inspection to measure BOZR and Diameter, conforming to the current ISO standards.

2. Methods

The two instruments used in the study were the Optimec JCF and the Optimec is830 development instrument (both manufactured by Optimec Limited, Malvern, UK). The JCF is a widely adopted projection based instrument; the is830 is an OCT-based instrument that uses interferometry to produce an image of transparent or semi-transparent samples. Both instruments are described in more detail below.

2.1. Instrumentation—JCF

The Optimec JCF is a projection based instrument incorporating two temperature controlled wet cells (in the current study controlled by an Optimec TC20i at 20 °C to ±0.5 °C). The first cell allows measurement of the lens diameter by placing a lens onto a graticule with the lens and graticule projected and magnified by ×17 to allow measurement with a visual scale giving a resolution of ±0.025 mm (Fig. 1B). The second cell uses a cylinder and probe to calculate the BOZR by utilising the sagittal height across a 10 mm chord method (ISO 18369-3:2006 Section 4.1.4.2.2, [1]), with a resolution of ±0.02 mm. There is also a projected image (×20) of the lens (Fig. 1A) allowing the centre thickness to be estimated using a scale on the screen (resolution of ±0.05 mm), where the centre thickness is calculated from the scale position of the top of the lens and the position of the top of the probe once the lens has been removed from resting on the probe. To complete all measurements after lens stabilisation typically takes 45–50 s for a trained operator.

2.2. Instrumentation—is830

The Optimec is830 is a spectral domain OCT-based instrument utilising custom de-warping and image processing software and a unique lens handling solution to ensure suitable hydration and temperature control of lenses. The OCT technology allows for the complete geometric characterisation of the contact lens anterior and posterior surfaces, for samples immersed in a fluid or in air. The test instrument in the current study is a pre-production

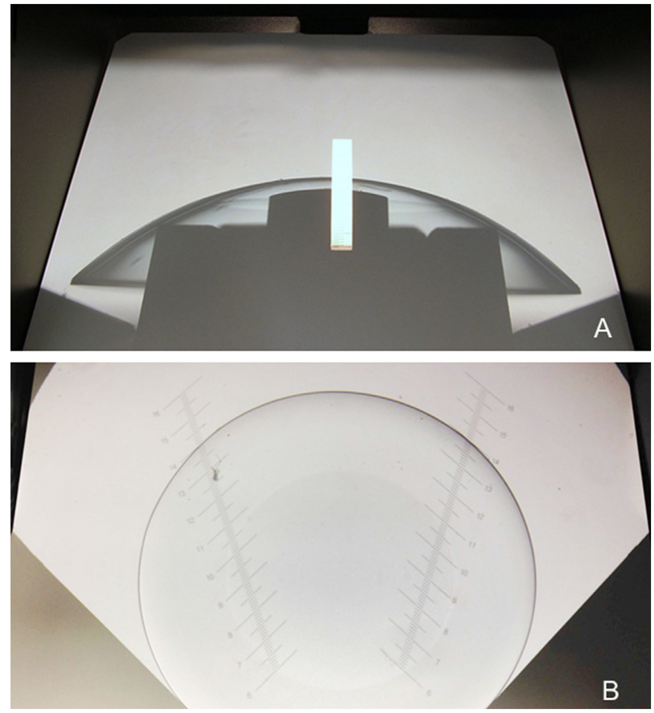

Fig. 1. Illustration of the Optimec JCF measurement methods. (A) Illustration of the BOZR and centre thickness measurement utilising a cylinder and pillar for measurement of BOZR via the sagittal height, in addition to a visual scale for centre thickness inspection. (B) Illustration of the diameter measurement cell utilising a graticule with a left and right scale for visual inspection.

prototype configured for measurement in saline, but can be adapted to measure samples in air.

A schematic of the instrument is shown in Fig. 2. A super luminescent diode (SLD) light source is split between a sample and reference arm by a fibre couple. A Micro-Electrical-Mechanical (MEMs) mirror system is used to scan the light source across a sample, the return reflections are then combined with the return signals from the reference arm and analysed by a spectrometer to characterise the lens. The instrument has a measurement volume of 20 × 20 × 6 mm with an axial resolution in air of 12 μm and a lateral resolution of 30 μm, which can be improved with additional scanning. A camera is used with a beam splitter to image the sample from above.

The contact lens is inserted into the lens cell, and supported on a lens holder. The lens holder contains a number of support arms

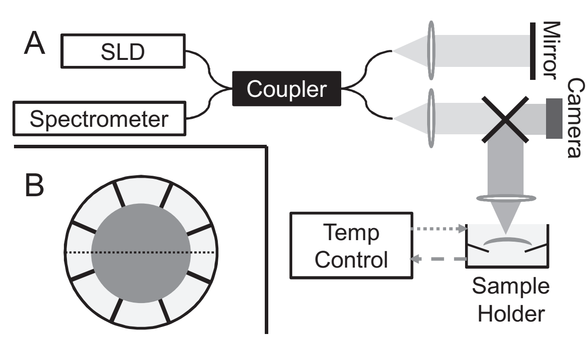

Fig. 2. Experimental setup. (A) Optimec is830 SD-OCT arrangement of SLD light source, reference arm and sample arm, with a camera aligned centrally on the sample holder. Light from the SLD is split by the fibre couple before return signals are combined and received at the spectrometer. Temperature control is used to regulate the saline that the lens sample is immersed in. (B) Optimec is830 lens sample holder detail, illustrating the contact lens (blue), lens support arms (solid lines) and example scan lines (dotted).