Correlation Between Central Corneal Thickness, Anterior Chamber Depth, and Corneal Keratometry as Measured by Oculyzer II and WaveLight OB820 in Preoperative Cataract Surgery Patients

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ABSTRACT

PURPOSE: To compare and correlate central corneal thickness (CCT), anterior chamber depth (ACD), and keratometric (flat and steep K) measurements using two anterior segment imaging methods, a Scheimpflug camera system (Oculyzer II [Oculus Optikgeräte GmbH]), and a partial coherence biometry system (WaveLight OB820 [Alcon Laboratories Inc]) in eyes undergoing cataract surgery.

METHODS: Ninety patients (mean age: 66±13 years [range: 32 to 88 years]) underwent preoperative measurement of central corneal thickness, anterior chamber depth, and keratometric measurements by Scheimpflug tomography (Oculyzer II) and optical low coherence reflectometry (WaveLight OB820). Interdevice agreement and correlation between the two techniques were assessed.

RESULTS: All measurements were highly correlated, and showed no clinically significant difference between methods. Mean CCT was 554.21±39.07 μm and 546.59±37.75 μm for the Oculyzer II and WaveLight OB820, respectively (R^2=0.9268). Mean ACD was 2.63±0.44 mm and 2.63±0.43 mm for the Oculyzer II and WaveLight OB820, respectively (R^2=0.9488). The principal meridian keratometric values were also highly correlated. Mean flat K was 42.88±1.50 diopters (D) and 42.96±1.40 D for the Oculyzer II and WaveLight OB820, respectively (R^2=0.8741). Mean steep K was 44.08±1.79 D and 44.26±1.95 D for the Oculyzer II and WaveLight OB820, respectively (R^2=0.9159).

CONCLUSIONS: Our data show that the Oculyzer II and WaveLight OB820 provide measurements that are in agreement with published values for CCT and ACD in patients. Excellent agreement for CCT and ACD was found between the two devices, as demonstrated by a high degree of correlation and linearity, in addition to minimal bias. Thus, CCT, ACD, and K measurements by these instruments can both be used in clinical preparation, and their agreement is an ensuring precision factor for cataract and refractive surgeons. [*J Refract Surg*. 2012;xx(x):xxx-xxx.]

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Biometry is a basic and necessary examination that must be performed prior to cataract surgery. Ongoing improvement of intraocular lens (IOL) design (accommodating, multifocal, aspheric, astigmatic, etc) requires high precision biometry calculations.[1] Therefore, increased precision and accuracy of biometry measurements is essential in any preoperative measurement.

Biometry determines the refractive power of the IOL as well as its effective lens position and helps achieve the targeted postoperative refraction. To this aim, several preoperative data have to be collected to be included in formulae such as the Olsen,[2] Haigis-L,[1,3] Holladay 2,[4,5] and Hoffer Q.[6] These data include corneal refractive power (by measuring steep and flat meridian keratometry [K]) and ocular axial length. In addition, central corneal thickness (CCT, defined as the distance between the anterior corneal surface and posterior corneal surface) and aqueous or anterior chamber depth (ACD, defined as the distance between the anterior corneal surface and anterior crystalline lens surface) are also measured by biometry devices.

Central corneal thickness measurement is important for ensuring proper intraocular pressure correction in individuals with increased glaucoma risk, and ACD measurement is important for its correlation with axial length and its association with increased risk for angle closure if the anterior angle is shallow, particularly for hyperopic individuals.

BIOMETRY DEVICES

The IOLMaster (Carl Zeiss Meditec, Jena, Germany) was the first US Food and Drug Administration–approved noncontact, optical biometry device to use partial coherence in-

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TABLE 1

Parameters Measured by Oculyzer II and WaveLight OB820

	Mean±Standard Deviation (Range)	
Parameter	**Oculyzer II**	**WaveLight OB820**
CCT (μm)	554.21±39.07 (448 to 640)	546.59±37.75 (466 to 633)
ACD (mm)	2.63±0.44 (1.77 to 3.61)	2.63±0.43 (1.78 to 3.55)
Flat K (D)	42.88±1.50 (40.50 to 48.90)	42.96±1.40 (39.40 to 47.05)
Steep K (D)	44.08±1.79 (40.90 to 52.30)	44.26±1.95 (40.73 to 54.39)

CCT = central corneal thickness, ACD = anterior chamber depth, flat K = flat meridian keratometry, steep K = steep meridian keratometry

terferometry and has superseded keratometers for corneal refraction measurement and A-scan ultrasound systems for axial length measurement.[7]

One of the most current, noncontact, optically based biometry devices is the WaveLight OB820 (Alcon Laboratories Inc, Ft Worth, Texas). It is a fully automated partial interferometry system, and is considered the first optical biometer that uses optical low-coherence reflectometry, a technology similar to time-domain optical coherence tomography (OCT), for all measurements, including CCT, ACD, and crystalline lens thickness.[8] Thus, the WaveLight OB820 is considered a biometer of the entire eye,[9] as one scan consists of 16 individual full eye scans and 4 individual keratometric scans, taken on 2 concentric rings, along the eye's visual axis.

ANTERIOR SEGMENT IMAGING DEVICES

Optically based anterior segment imaging technologies are well-established, as they provide excellent resolution, acquisition time is short (few seconds), and alignment is naturally aided via a fixation target and an optical image of the eye during acquisition.

The three major optical systems for anterior segment imaging are: 1) scanning slit-lamp combined with topography[10,11] (eg, Orbscan [Bausch & Lomb, Rochester, New York]), 2) anterior segment OCT[12], and 3) rotating Scheimpflug cameras[13] (eg, Pentacam [Oculus Optikgeräte GmbH, Wetzlar, Germany]).

Optical coherence tomography is referred to as an optical analog to ultrasound, but detects optical instead of acoustic backscatter. In the more recently developed frequency (also Fourier or spectral) domain OCT, the broadband signal is broken into a spectrum using a grating or linear detector array, and depth is determined from the spectrum Fourier transform without motion along the reference arm. This allows data along one line of sight to be acquired virtually instantaneously, with the acquisition speed of the photodetector becoming the rate-limiting factor.

In our clinical practice, we evaluate Oculyzer II (Oculus Optikgeräte GmbH) and WaveLight OB820 imaging to reduce the chance of interexaminer and interdiagnostic error on all patients examined as general ophthalmology consults or refractive or cataract surgery candidates.

PATIENTS AND METHODS

This study received ethics committee approval, and informed consent was obtained from each patient. The present study was conducted on virgin corneas of normal eyes with no ocular pathology other than refractive error and cataract. A complete ocular examination was performed to screen for corneal abnormalities.

Ninety preoperative cataract surgery patients (47 female, 43 male, all Caucasian) were studied over a 4-month period during their scheduled preoperative visit in our practice between January and April 2012. Patients were excluded from the study if they had been previously operated, were wearing contact lenses (which may cause temporary steepening or flattening), had any history of ocular disease, including glaucoma, or the presence of any other sign of compromised corneal health. In patients for whom bilateral scans were performed, one eye from each patient was selected randomly using coin toss between right and left eye. Patient age ranged from 32 to 88 years (mean: 66±13 years).

The same trained investigator (G.A.) performed all measurements on all patients using each modality, Oculyzer II and WaveLight OB820. Each patient's data were collected at the same time of day, consecutively via the two modalities. All devices were calibrated according to manufacturer recommendations prior to undertaking the measurements.

Oculyzer II measurements were obtained and processed via the Oculyzer software (version 1.17r91). The default setting of 25 images per acquisition was used.

Linear regression analysis was performed to seek possible correlations of CCT, ACD, and K-readings between the two modalities. Descriptive statistics (average, minimum, maximum, standard deviation, and range), comparative statistics, and linear regression were performed in Microsoft Excel 2010 (Microsoft Corp, Redmond, Washington) and Origin version 8 (OriginLab Corp, Northampton, Massachusetts). Analysis of variance between groups was performed via the Origin statistics tool.

TABLE 2

Comparative Statistics Between Oculyzer II and WaveLight OB820 Data

Statistic	CCT	ACD	Flat K	Steep K
Correlation coefficient (R^2)	0.9268	0.9786	0.8741	0.9159
Linearity	0.9302	0.9488	0.9443	1.0383
Two-tailed *P* value	<.0001	<.0001	<.0001	<.0001
Bias	7.60 μm	0.008 mm	−0.135 D	−0.182 D
Corresponding to % of average value	1.38%	0.30%	−0.31%	−0.41%
LoA @ 95% CI (lower - upper)	−13.1 μm 28.3 μm	−0.122 mm 0.138 mm	−1.098 D 0.829 D	−1.30 D 0.93 D

CCT = corneal thickness, ACD = anterior chamber depth, K = keratometry LoA = limits of agreement, CI = confidence interval

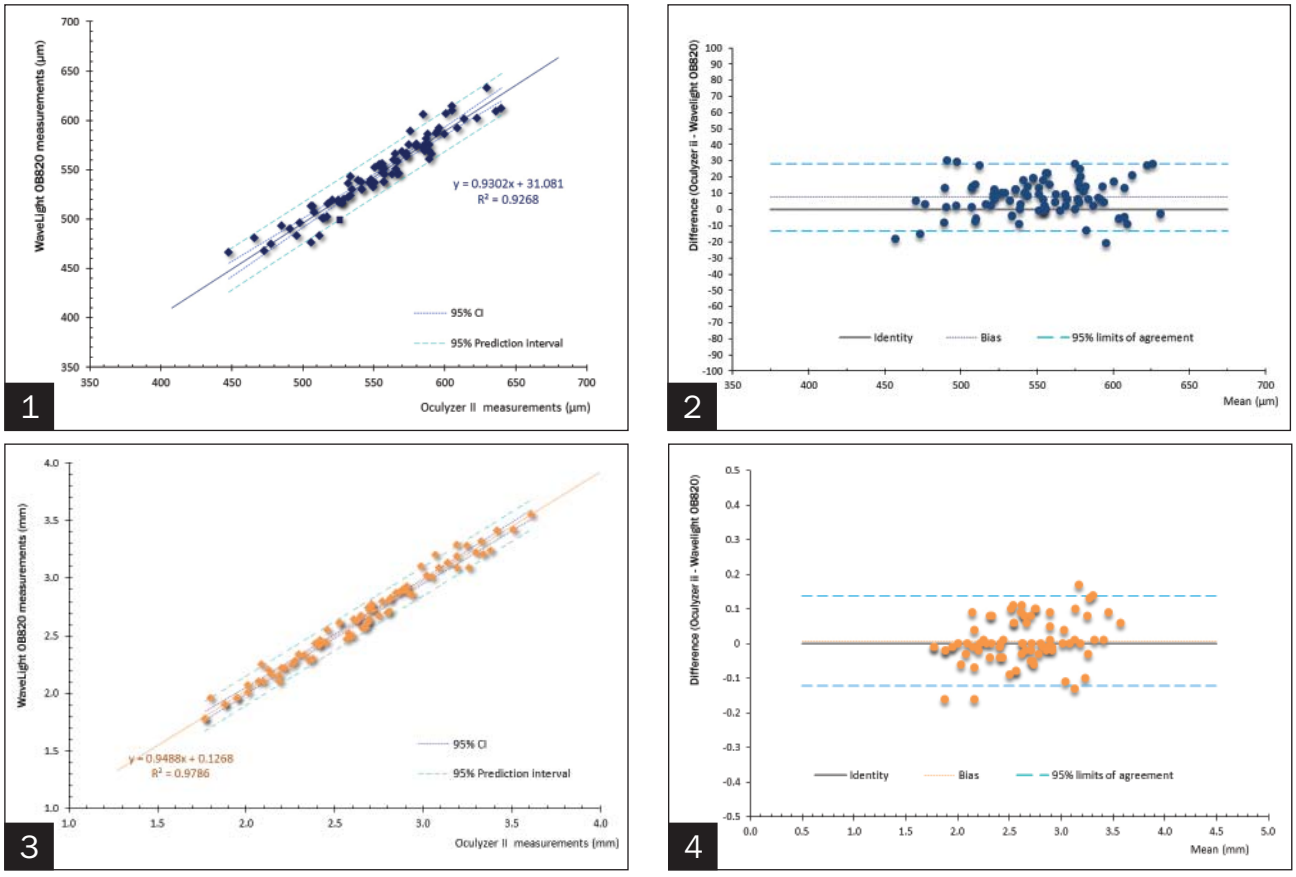

Figure 1. Scatterplot depicting correlation between Oculyzer II and WaveLight OB820 central corneal thickness measurements with linearity coefficient and coefficient of determination (R^2) (CI = confidence interval). **Figure 2.** Bland-Altman plot comparing central corneal thickness measurements between Oculyzer II and WaveLight OB820 with bias and 95% limits of agreement. **Figure 3.** Scatterplot depicting correlation between Oculyzer II and WaveLight OB820 anterior chamber depth measurements with linearity coefficient and coefficient of determination (R^2) (CI = confidence interval). **Figure 4.** Bland-Altman plot comparing Oculyzer II and WaveLight OB820 anterior chamber depth measurements with bias and 95% limits of agreement.

RESULTS

As shown in Tables 1 and 2, there was excellent correlation between the two devices for all studied parameters. Specific data for all parameters are presented in Figures 1-8.

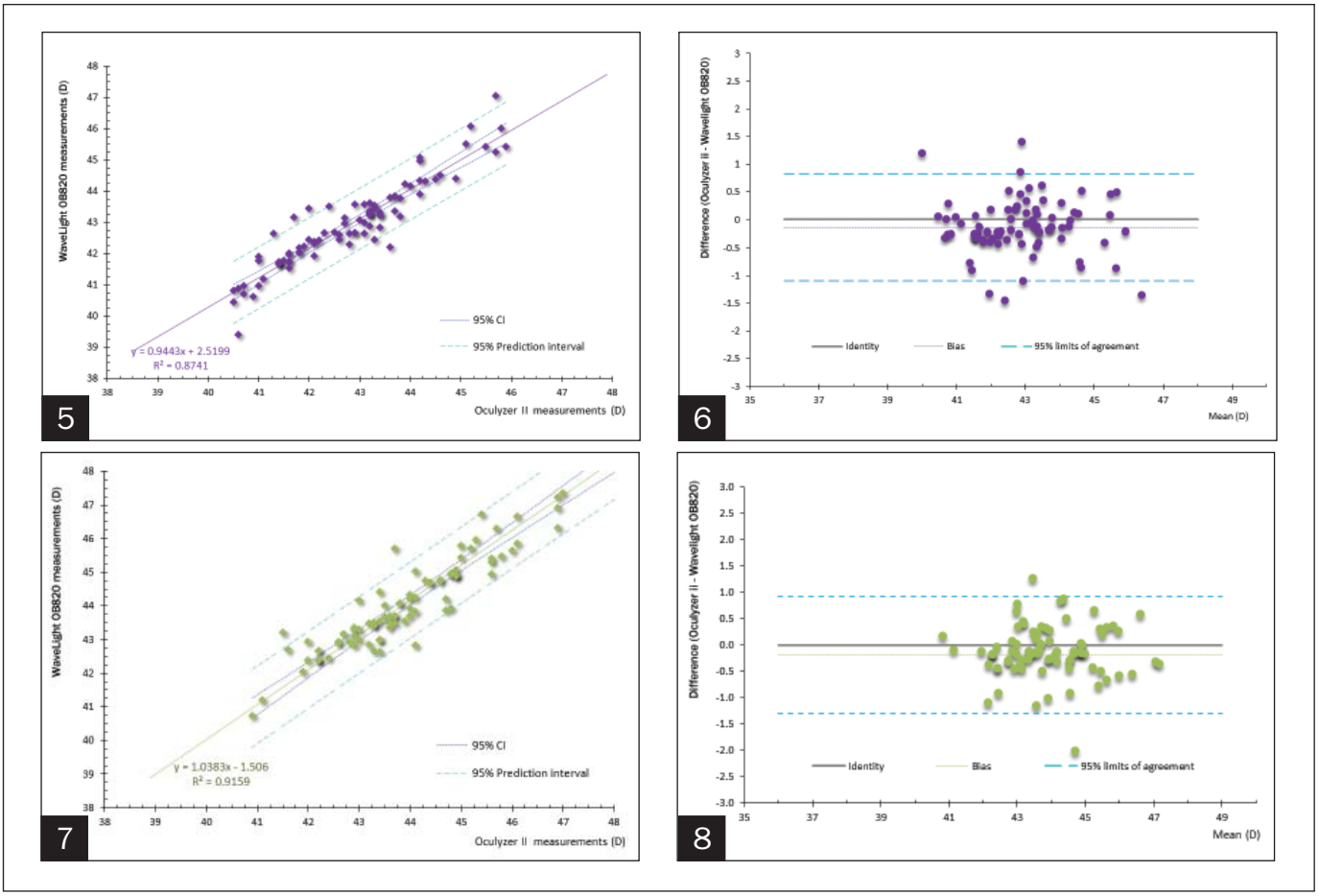

Figure 5. Scatterplot depicting correlation between Oculyzer II and WaveLight OB820 flat keratometry measurements with linearity coefficient and coefficient of determination (R^2) (CI = confidence interval). **Figure 6.** Bland-Altman plot comparing Oculyzer II and WaveLight OB820 flat keratometric measurements with bias and 95% limits of agreement. **Figure 7.** Scatterplot depicting correlation between Oculyzer II and WaveLight OB820 steep keratometry measurements with linearity coefficient and coefficient of determination (R^2) (CI = confidence interval). **Figure 8.** Bland-Altman plot comparing Oculyzer II and WaveLight OB820 steep keratometry measurements with bias and 95% limits of agreement.

DISCUSSION

Our data show that the Oculyzer II and WaveLight OB820 provide measurements that are in agreement with published values for CCT,[14-16] ACD, and K-values[17-24] in normal and preoperative cataract surgery patients. Literature suggests that mean CCT normally varies among Caucasian people with an average of 540 to 550 µm, which is in agreement with our data: WaveLight OB820, mean 546.59 µm; Oculyzer II, mean 554.21 µm. The average young adult eye has ACD of 3.15 mm,[25] but it is commonly accepted that it decreases by 0.01 mm per year. This is in excellent agreement with our findings, as shown in Figure 9, where the linear fit line of both Oculyzer II and WaveLight OB820 ACD versus age is displayed. (The data are highly normalized, as demonstrated by the standardized residual plots and normal fit shown in Figure 10 for the Oculyzer II ACD measurements.) Thus, for the mean patient age of 66 years in the current study, an ACD of 2.5 mm is considered representative (our data: WaveLight OB820, mean 2.63 mm; Oculyzer II, mean 2.63 mm). In addition, the average corneal refractive K value is reported at 43.00 to 44.00 D (our data: WaveLight OB820, mean 42.96/44.26 D; Oculyzer II, mean 42.88/44.08 D, for flat/steep meridians, respectively).

We find that in the set of measurements provided by both systems (ie, CCT, ACD, and K), an excellent degree of correlation with minimal bias exists. Of the two modalities examined, the Oculyzer II features the largest number of acquired images per scan (although we used 25 in the present study per our protocol, there is an option to acquire 50 images) compared to the 9 for the WaveLight OB820. It is, therefore, expected that the most detailed and accurate pachymetry maps result from the Oculyzer II; however, the comparison is valid only for the corneal apex, provided that precise pupil centering was achieved during acquisition.

It is encouraging that the most positively correlated

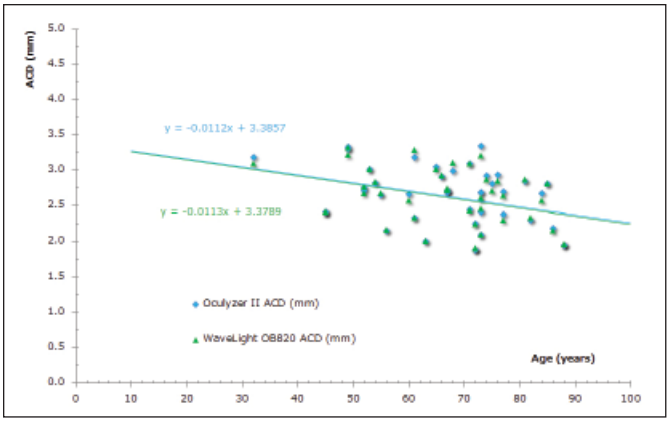

Figure 9. Scatterplot depicting correlation between anterior chamber depth (ACD) and age. The negative slope of the trend lines (−0.0104 and −0.0106 for the Oculyzer II and WaveLight OB820, respectively) are indicative of the rate at which the ACD decreases per year.

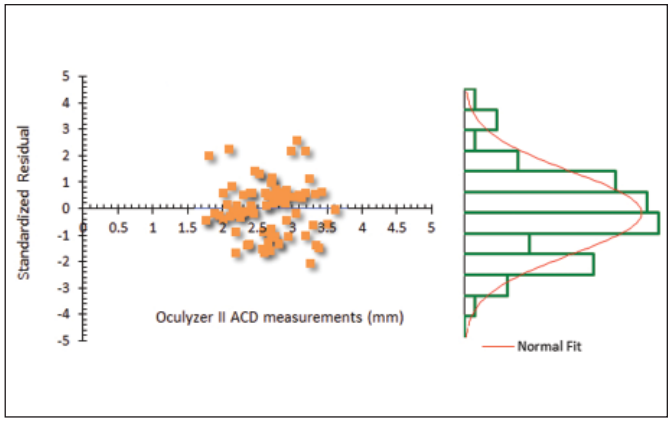

Figure 10. Anterior chamber depth (ACD) measurements via the Oculyzer II showing normalization.

set of data, featuring the lowest bias, was measured for ACD. Precise ACD measurement is essential not only for patient selection to ensure a safe distance of the lens from the iris and other anterior anatomical elements, but is also an important parameter to consider in phakic IOL calculation formulae. In our set of data, the bias (Oculyzer II–WaveLight OB820) was only 8 µm (0.008 mm, corresponding to 0.3% of the average ACD and 0.0035 D target refractive error according to the Haigis formula), limit of agreement (LoA) was likewise very tight (−0.122 to 0.138 mm), the linearity of the trend line was excellent (WaveLight OB820 measurements=0.9488×Oculyzer measurements), and the coefficient of correlation was almost unity (R^2=0.9786).

Previous studies of ACD measurements comparing Pentacam to other traditional devices such as the IOLMaster (Carl Zeiss Meditec) and ultrasound have yielded mixed results. In one study, the Pentacam differed significantly from the IOLMaster, with the Pentacam bias by approximately 0.05 mm,[25] while in another by 0.10 mm.[26] This range of ACD uncertainty (0.05 to 0.1 mm) corresponds to a refractive error discrepancy of 0.025 to 0.05 D for a standard posterior chamber IOL.

Central corneal thickness measurements were also highly correlated. In our set of data the bias (Oculyzer II–WaveLight OB820) was only 7.6 µm (0.0076 mm, corresponding to 1.37% of the average CCT), LoA was likewise close (−13.1 to 28.3 µm), the linearity of the trend line was excellent (WaveLight OB820 measurements=0.93×Oculyzer measurements), and the coefficient of correlation was almost unity (R^2=0.93).

On the other hand, of the four pairs of data sets, the least correlated data (although still very well correlated), were found among the keratometric data. This can be explained by the fact that the Oculyzer II obtains refractive maps from the entire corneal surface and computes specific K readings for each zone of 3-, 5-, and 7-mm diameter. It is quite unusual that any cornea will have the exact keratometric readings (including, but not limited to, shift of the principal meridian) in all three zones. On the other hand, the keratometric values reported by the WaveLight OB820 are considered a more "average" reading.

Our data show that the Oculyzer II and WaveLight OB820 provide measurements that are in agreement with published values for CCT and ACD in patients. Excellent agreement for CCT and ACD was found between the two devices, as demonstrated by a high degree of correlation and linearity, in addition to minimal bias. Thus, CCT, ACD, and K measurements from these instruments can be used in clinical preparation and their agreement is an ensuring precision factor for any cataract or refractive surgeon.

AUTHOR CONTRIBUTIONS

Study concept and design (A.J.K., G.A.); data collection (G.A.); analysis and interpretation of data (A.J.K., G.A.); drafting of the manuscript (G.A.); critical revision of the manuscript (A.J.K.); statistical expertise (G.A.); obtained funding (A.J.K.); administrative, technical, or material support (A.J.K.); supervision (A.J.K.)

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