Assessment of differences in ocular morphometric measurements by using optical and applanation ultrasound biometry in the same eye

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SUMMARY

Purpose of this work was to determine the differences in ocular axial length measurements carried out by one investigator using optical and ultrasound biometry on the same eye.

In a prospective study, we measured the ocular axial length in 30 eyes of 30 different patients with the non-contact optical IOLMaster™ (Zeiss Humphrey System, CA, USA) and immediately afterwards with the ultrasonic Compuscan A-B (Storz, St. Louis, MO, USA). One investigator took three consecutive readings of the ocular axial length with both biometers; the means of these three consecutive readings were the ocular axial length values used in the study. The mean age of the sample was 33.55±8.32 years (range, 21 to 54 years). 23.33% (7 eyes) of the biometric procedures were conducted in women and 76.66% (23 eyes) in men. A t-Test for paired data was used to confirm the differences between the two measurement tools. $P<0.05$ was considered to be statistically significant.

All measurements made with the IOLMaster™ unit were higher than those obtained with the Compuscan unit. The IOLMaster™ unit measurements were on average 0.38±0.20 mm higher than the Compuscan measurements ($p<0.001$). The mean ocular axial length was 23.82±2.18 mm as measured with the IOLMaster™ and 23.43±2.14 mm with the Compuscan A-B. The minimum difference between optical and ultrasound biometry was 0.12 mm and maximum was 0.74 mm.

Optical and ultrasound biometry are two efficient anatomical tools for study of ocular anatomy. However, all anatomists should take into account the differences between the optical and ultrasound results when carrying out anatomical ocular studies in vivo.

Key Words: Axial length – Biometry – Optical – Ultrasound – Morphometry – Non-contact

INTRODUCTION

The introduction of ultrasound in Ophthalmology (Mundt and Hughes, 1956) has allowed us to increase our knowledge of ocular anatomy. Ultrasound biometry has been recognised as an efficient anatomical tool and, through this technique, in recent years several authors have studied eye size length.

Ultrasound biometric studies have been useful in detecting a shorter ocular axial length in hyper-

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opic eyes whilst myopics show higher values (McBrien and Adams, 1997; Osuobeni, 1999; Hosny et al., 2000). Other studies have demonstrated that women have a shorter mean ocular axial length as compared to men (Fledelius, 1995; Lin et al., 1996; Lam et al., 1999; Osuobeni, 1999; Wong et al., 2001).

Ultrasound has enabled researchers to establish eye size length values in populations of schoolchildren (Lam et al., 1999) as well as in elderly populations (Fledelius, 1988; Midelfart and Aamo, 1994; Connell et al., 1997). Furthermore, ultrasonic biometry has been used in different longitudinal studies to follow up changes in eye size length (Grosvenor and Scott, 1993; Lin et al., 1996; Lam et al., 1999).

Recently, however, optical biometry based on partial coherence interferometry has been presented as a new anatomical tool in order to study ocular axial length (Hitzenberger et al., 1993; Schmid et al., 1996; Findl et al., 1998; Drexler et al., 1998a, 1998b; Haigis et al., 2000; Lam et al., 2001). This new technique allows ocular axial length measurements to be carried out in a similar fashion to ultrasound but by emitting light waves instead of acoustic waves. The instrument measures –by virtue of an interferometer– the time that elapses for light to be reflected from different tissues; the time will depend on the microstructures of such tissues. Laser interferometric biometry allows eye size length measurements to be carried out while avoiding contact with ocular surface. With this optical technique it is possible to measure ocular axial length without anaesthetising the cornea.

Despite this, applanation ultrasound biometric studies have been carried out with different commercial biometers while until recently laser interferometric studies have been carried out with non-commercial experimental prototypes (Haigis et al., 2000; Lam et al., 2001). Recent introduction of the commercial optical Zeiss IOLMaster™ biometer has allowed anatomists to compare and to detect in vivo differences between optical and ultrasonic ocular morphometric results.

It is very important to detect these differences in anatomical ocular axial length results because it is necessary to measure the ocular axial length to establish the intraocular lens power before surgery (Drexler et al., 1998a; Haigis et al., 2000). This is specially significant because it has been reported that the measurement of ocular axial length constitutes the largest source of error in intraocular lens calculation (Olsen, 1992).

Following on from this, in the present work we wished to evaluate the differences in ocular axial length measurements obtained by one investigator with the commercial optical IOLMaster™ (Zeiss Humphrey System, CA, USA) in comparison with results obtained with the commercial ultrasonic Compuscan A-B (Storz, St. Louis, MO, USA).

Materials and Methods

In a prospective study we measured ocular axial length in 30 eyes of 30 different patients with the non-contact optical IOLMaster™ (Zeiss Humphrey System, CA, USA) and immediately after with the ultrasonic Compuscan A-B (Storz, St. Louis, MO, USA). All procedures were conducted in accordance with the principles of the Helsinki Declaration. Detailed consent forms were obtained from each of the patients.

Exclusion criteria included previous intraocular surgery, contact lens wear, corneal pathology, any degree of significant cataract, intraocular pressure ≥ 21 mm Hg or glaucoma, vitreous and retinal pathology, use of any kind of ophthalmic or systemic drugs, and advanced systemic disease. The mean age of the sample was 33.55±8.32 years (range, 21 to 54 years). 23.33% (7 eyes) of the biometric procedures were conducted in women and 76.66% (23 eyes) in men.

One investigator (JASG) took three consecutive readings with both biometers and the mean of these three consecutive readings of ocular axial length were the values used in the study. Only the patients' right eyes were analysed. The choice of limiting the study to the right eye instead of the left eye was random. Examinations were done at the same time of the day (10 AM to 11 AM) and only one patient was analysed per day.

The principles of optical biometry with the IOLMaster™ are well documented (Haigis et al., 2000). The technique involves the use of an infrared diode laser (780 nm) for calculating ocular axial length. As done by Lam et al. (2001), we followed the procedures recommended by the manufacturer in order to obtain ocular axial length measurements. For IOLMaster™ biometry, the patient was positioned with the chin in a cup and the forehead against a headband. Ocular axial length was measured while the patient focused on a fixation light in the instrument. Optical biometry with the IOLMaster™ measured the distance between the anterior surface of the tear film and the pigmented epithelium. No optical IOLMaster™ measurements could be obtained from 3 patients, who were therefore excluded.

After the IOLMaster™ ocular axial length measurements, the same investigator took three consecutive ultrasonic readings, as recommended by Butcher and O'Brien (1991), using a 10-MHz A-mode Compuscan A-B (Storz, St. Louis, MO, USA). For Compuscan biometric readings, after anaesthetising the cornea with two drops of oxybuprocaine 0.4%, the patient was required to look straight ahead while the ultrasonic probe was placed in the centre of the cornea. With ultrasonic biometry we measured the distance between the anterior surface of the cornea and the limiting membrane.

The biometric results were accepted as valid if after repeating the procedures with a 15 minute interval between them the results obtained were the same as the previous ones ± 0.10 mm (with both biometers). These second measurements were employed for the statistical study. Measurements were not taken into account in case of non-coincidence with respect to previous results.

Statistical work was carried out using the SPSS statistical programme (SPSS v10.0, SPSS Inc, Redmon, WA). The statistical study consisted of a descriptive and a bivariate analysis. Furthermore, the t-Test for paired data was used to confirm the differences between the two measurement tools. Prior to this, the normal distribution of the sample was contrasted by the non-parametric Kolmogorov-Smirnov test. A p-value less than 0.05 was considered to be statistically significant.

RESULTS

Mean ocular axial length was 23.82±2.18 mm as measured with the IOLMaster™ and 23.43±2.14 mm as determined with the Compuscan A-B. All measurements made with the IOLMaster™ device were higher than those performed with the Compuscan unit. A paired t-test showed this difference to be significant ($p<0.001$).

Minimum ocular axial length was 21.47 mm and 21.24 mm with the IOLMaster™ and Compuscan devices respectively. Maximum ocular axial length with the IOLMaster™ unit was 30.73 mm and 30.18 mm with the Compuscan. The minimum difference between the two biometers was 0.12 mm and the maximum was 0.74 mm. The IOLMaster™ unit measurements were on average 0.38±0.20 mm higher than the Compuscan measurements ($p<0.001$).

Figure 1 shows the differences in ocular axial length values observed in each eye after carrying out measurements with the IOLMaster™ and consecutively with the Compuscan unit.

The differences observed between the two biometers were ≤ 0.25 mm in 13 eyes (43.33%); between 0.26 and 0.50 mm in 7 eyes (23.33%), and between 0.51 and 0.74 mm in 10 eyes (33.33%). Figure 2 shows the differences between the biometers grouped by values.

As can be seen in Figure 2, most of the differences in ocular axial length values ranged from 0.16 to 0.25 mm; nevertheless in a considerable percentage of eyes the difference was greater than 0.66 mm.

DISCUSSION

Non-contact biometric techniques are currently seen as a good alternative to applanation ultrasound biometry because they have a number of advantages. The main clinical advantage of these techniques is that applanation ultrasound biometry poses a possible risk of infections, due to ultrasound probe contact; this problem can be avoided with the use of non-contact techniques. Table 1 summarises the advantages of non-contact optical biometry as compared to applanation ultrasound biometry.

Table 1.- Advantages of non-contact optical biometry.

- Avoids risk of infection transmittance
- More patient comfort
- Greater speed
- Easier to use
- Experienced observers not necessary
- No anaesthetic required
- Corneal indentation is avoided
- Possibility of multiple consecutive measurements
- Measurements are operator-independent.
- Avoids risk of corneal lesions

Here, we detected significant differences between optical and applanation ultrasound biometry in ocular axial length measurements carried out by an experienced observer. In our study, we found that the IOLMaster™ afforded measurements that were 0.38±0.19 mm higher than those from the ultrasonic Compuscan A-B. Higher differences were previously obtained by Hitzemberger et al. (1993) and Drexler et al. (1998a). Hitzemberger et al. (1993) obtained a difference in ocular axial lengths of 470±250 µm, while Drexler et al. (1998a) observed a difference of 460±201 µm when they compared optical and applanation ultrasound measurements. A possible reason for this difference is that Hitzemberger et al. (1993) and Drexler et al. (1998a) did not use the same machines as the ones used by us. Recently, using the IOLMaster™ Lam et al. (2001) reported smaller differences than those found in the present work. They obtained applanation ultrasound values of 24.54±1.09 mm and 24.44±1.21 mm with the IOLMaster™ on the same sample (n=26).

In our study, all biometric measurements were carried out by the same individual (JASG). With only one observer, we attempted to avoid possible differences in corneal indentation that occur among various observers when applanation ultrasound techniques are used (Bovelle et al., 1999). Furthermore, it has been reported that applanation ultrasound could elicit a possible shortening of ocular axial length due to globe compression during transducer contact (Drexler et al., 1998a; Haigis et al., 2000) and this could be one of the most important aspects accounting for the higher optical measurements obtained. The amount of shortening of ocular axial length during applanation can be obtained by comparing the results of non-contact immersion ultrasound techniques and applanation ultrasound

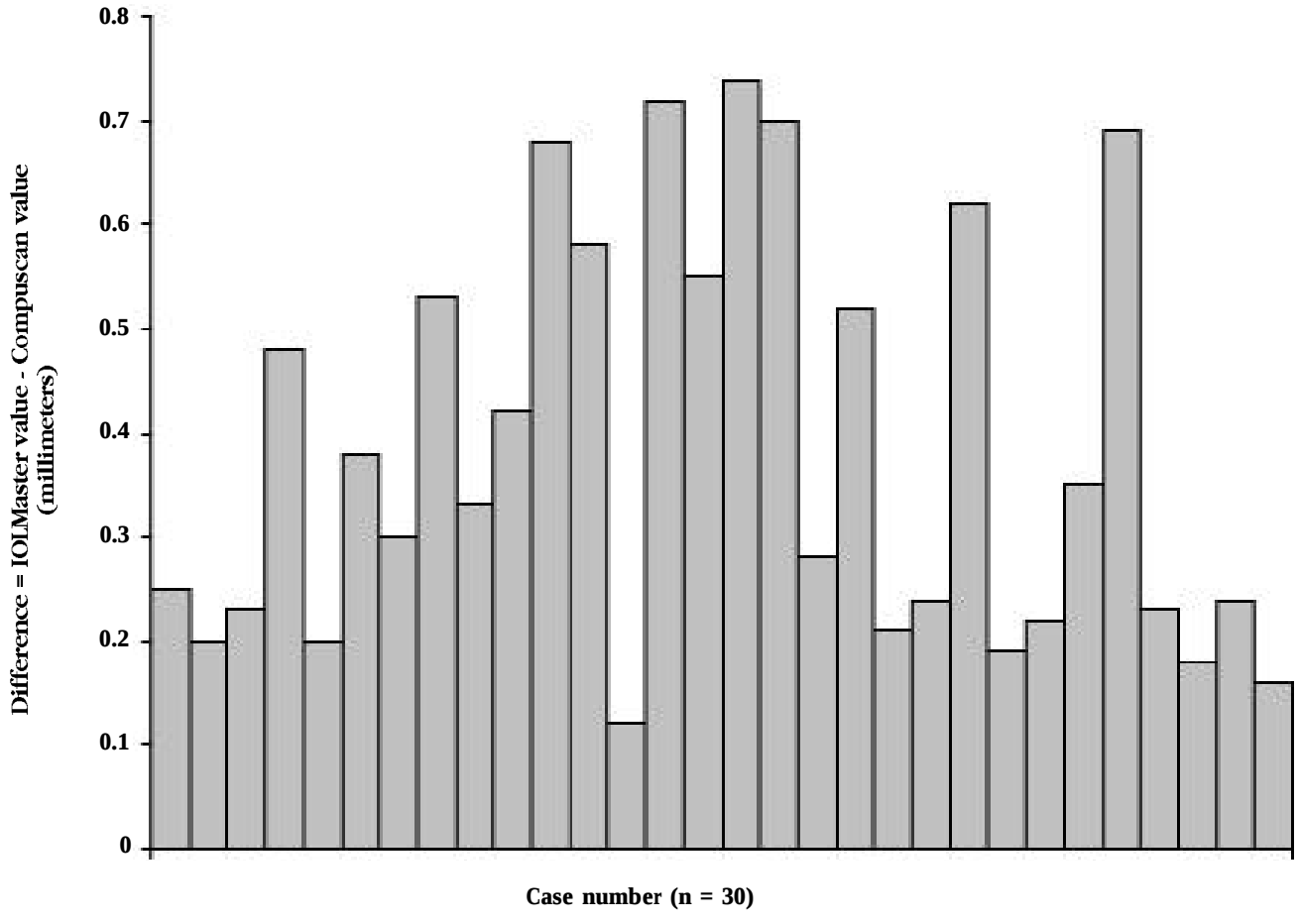

Figure 1.- Milimeters of difference observed in each patient eye after carrying out ocular axial length measurements with both biometers.

techniques obtained in the same eyes. Following on from this, it should be noted differences in ocular axial length results have been found on comparing applanation and immersion ultrasound biometry. Thus, Olsen and Nielsen (1989) obtained a difference of 140±0.19 µm while Drexler et al. (1998a) obtained a difference of 280±101 µm.

Other causes of differences in axial eye lengths is related to the fact that ultrasonic biometry measures the distance between the anterior surface of the cornea and the limiting membrane, whereas the IOLMaster™ measures the distance between the anterior surface of the tear film and the pigmented epithelium. Drexler et al. (1998a) assumed that higher partial coherence interferometric readings could be due in part to the retinal thickness in the fovea, which is about 130 µm.

One important disadvantage of applanation ultrasound biometry is that it requires exhaustive previous training because the ultrasonic probe must be positioned subjectively in the centre of the pupil and at the same time a high degree of pressure must be avoided to avoid excessive corneal indentation. However, the results obtained with partial coherence interferometry by experienced and untrained observers do not differ significantly (Hitzenberger et al., 1994; Lam et al., 2001). As with optical biometry, high precision measurements can be obtained by untrained users and this should enable more ocular anatomical studies to be carried out in the future, including studies conducted in freshly operated eyes (Haigis at el., 2000).

However, optical biometry with the IOLMaster™ does have some drawbacks because in our study we could not obtain ocular axial length measurements in 3 patients (9.09%). Previous to our findings, Haigis et al. (2000), using the same IOLMaster™, were unable to carry out measurements in 12% of the eyes. This is relevant because the most important clinical application of optical biometry is to measure ocular axial length prior to cataract surgery and Hitzenberger et al. (1993) has previously reported that 9.5% of cataractous eyes were not measurable by laser interferometry. Furthermore, with optical biometry it is necessary to have the patients' co-operation and different ocular pathologies, such as mature cataracts, vitreous haemorrhage, maculopathy, retinal detachment and others, prevent optical biometry from being carried out (Haigis et al., 2000). Paradoxically, in these eyes, classical ultrasound biometry, despite all its disadvantages, must be used.

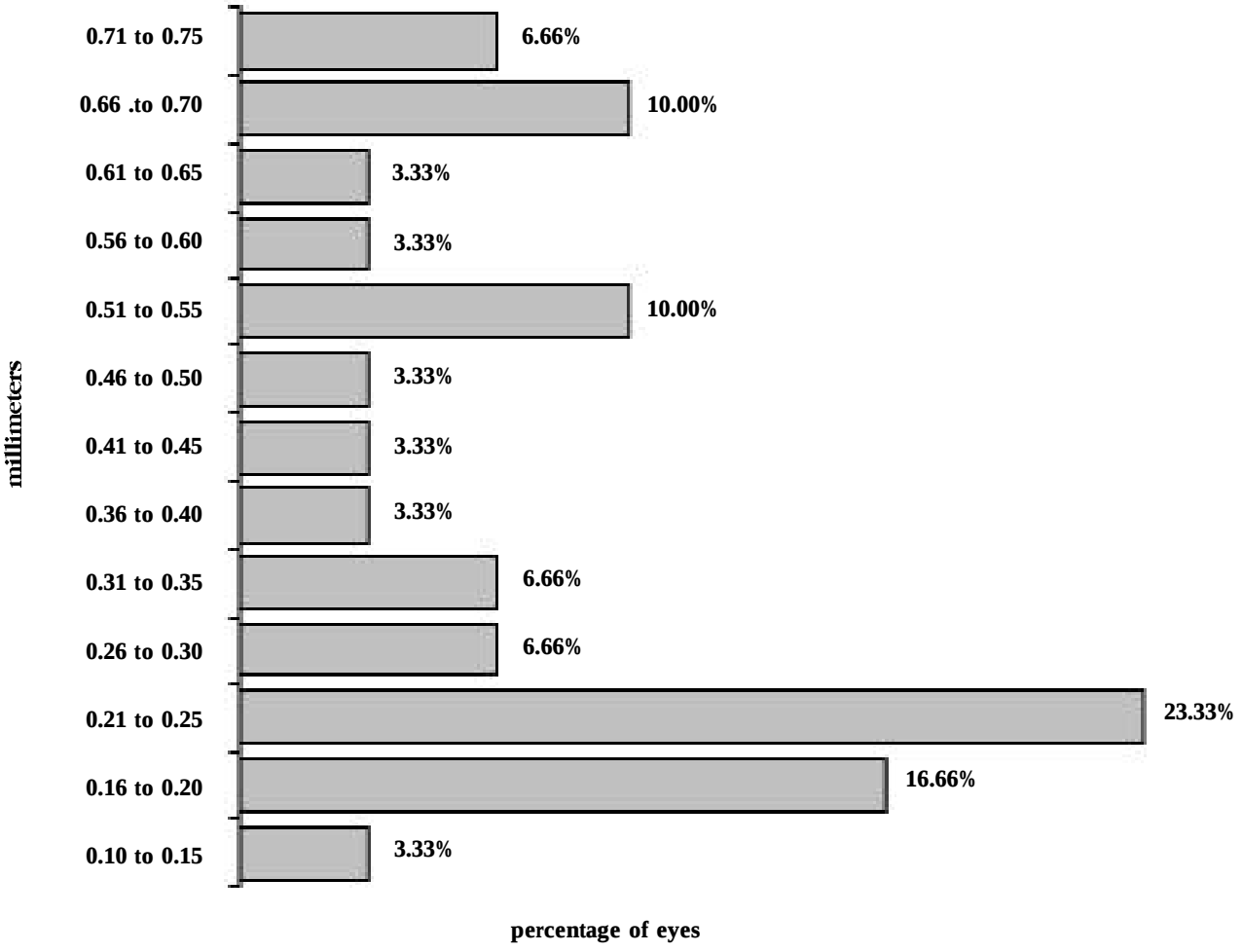

Figure 2.- Differences between biometers grouped by values (mm).

To sum up, optical and ultrasound biometry are efficient anatomical tools for the study of in vivo ocular anatomy; nevertheless optical biometry avoids some disadvantages inherent to ultrasonic biometry. In any case, anatomists should take into account the morphometric disparity between optical and ultrasonic results when carrying out ocular anatomical studies in vivo.

Finally, we recommend the use of laser interferometric biometry because it is a new and useful technology for ocular anatomical research that could contribute to enhancing our knowledge of ocular anatomical differences among populations and it may also enable innovations in anatomical studies of freshly operated eyes (Haigis et al., 2000), in which ultrasound technology can not be applied.

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