



ORIGINAL ARTICLE

The measurement of intraocular pressure over positive soft contact lenses by rebound tonometry



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KEYWORDS

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Hydrogel;
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Abstract

Purpose: To investigate if the accuracy of intraocular pressure (IOP) measurements using rebound tonometry over disposable hydrogel (etafilcon A) contact lenses (CL) is affected by the positive power of the CLs.

Methods: The experimental group comprised 26 subjects, (8 male, 18 female). IOP measurements were undertaken on the subjects' right eyes in random order using a Rebound Tonometer (ICare). The CLs had powers of +2.00 D and +6.00 D. Measurements were taken over each contact lens and also before and after the CLs had been worn.

Results: The IOP measure obtained with both CLs was significantly lower compared to the value without CLs (*t* test; $p < 0.001$) but no significant difference was found between the two powers of CLs.

Conclusions: Rebound tonometry over positive hydrogel CLs leads to a certain degree of IOP underestimation. This result did not change for the two positive lenses used in the experiment, despite their large difference in power and therefore in lens thickness. Optometrists should bear this in mind when measuring IOP with the rebound tonometer over plus power contact lenses.

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PALABRAS CLAVE

Lentes de contacto;
Hidrogel;
Tonometría de rebote;
Presión intraocular

Medición de la presión intraocular sobre lentes de contacto blandas positivas, mediante tonometría de rebote

Resumen

Objetivo: Investigar si la precisión de las mediciones de la presión intraocular (PIO), utilizando la tonometría de rebote sobre las lentes de contacto (LC) desechables de hidrogel (etafilcon A), se ve afectada por la potencia positiva de dichas lentes.

Métodos: El grupo experimental incluyó a 26 sujetos, (8 varones, 18 mujeres). Se realizó la medición de la PIO en los ojos derechos de los sujetos, de modo aleatorio, utilizando un Tonómetro de Rebote (ICare). Las LC tenían potencias de +2,00 D y +6,00 D. Se realizaron mediciones con cada lente de contacto, y también antes y después a su uso.

Resultados: El valor de la PIO obtenido con ambas LC fue considerablemente menor al valor sin LC (t del test; $p < 0,001$), aunque no se halló una diferencia significativa entre las dos potencias de las lentes.

Conclusiones: La tonometría de rebote sobre las LC positivas de hidrogel origina un cierto grado de subestimación del PIO. Este resultado no sufrió variación entre las dos lentes positivas utilizadas en el experimento, a pesar de la gran diferencia de potencia, y por tanto del espesor de las lentes. Los optometristas deberían de tener en cuenta estos resultados en a la hora de medir el PIO con un tonómetro de rebote, con lentes de contacto de mayor potencia.

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Introduction

Primary open angle glaucoma is a potentially blinding condition.¹ Raised intraocular pressure (IOP) is an important risk factor for the development and progression of optic nerve damage in glaucoma, and is the target of both medical and surgical treatment being currently the only treatable risk factor.²

Measuring IOP over a soft contact lens (CL) can be very useful for several reasons. These include avoiding topical anaesthesia, minimizing trauma in conditions of corneal pathology, whenever there is a need to undertake tonometry several times, when the corneal surface is extremely irregular and finally to allow IOP measurement without removing the CLs.³

Villani⁴ was probably the first to use a soft contact lens with contact tonometry having the aim of avoiding pharmacological anaesthesia. Several studies showed that measurement of IOP can be performed over soft contact lenses using the Goldmann tonometer,⁵⁻¹² the Mackay Marg tonometer,¹³ the Tono-Pen,¹⁴⁻¹⁷ the gas pneumotonometer,^{16,17} the non-contact tonometer¹⁸⁻²⁶ and the dynamic contour tonometer.^{11,27-29}

In 2005 a new handheld device became available to measure IOP, the ICare rebound tonometer, having the advantage over other instruments that no topical anaesthesia is required. A light magnetized small, disposable probe, characterized by a round plastic tip, is launched towards the eye using a solenoid. The probe hits the eye and bounces back. The return rate of the probe after it touches the cornea permits information about IOP.³⁰⁻³¹ The results are reproducible and reasonably accurate.³²⁻³³ Several investigators³⁴⁻⁴⁰ have evaluated the ICare tonometer compared with other tonometry devices, showing a

reasonable overall correlation and concordance between the IOP obtained with the Goldmann or Pascal types.

It has been shown that with the rebound tonometer it is possible to measure IOP over soft CLs, either hydrogel or silicone hydrogel, with good clinical accuracy.³⁹⁻⁴⁰ However it has been found that the type of material and the power of the CL can cause an underestimation of IOP⁴¹ or overestimation.^{25,42}

The aim of this study was to verify this effect not only for a +2.00 D CL but also for a higher positive +6.00 D CL. Other corneal parameters such as thickness and curvature were evaluated to investigate their influence on the measurement.

Methods**Subjects**

Twenty-six subjects (8 male and 18 female), age range from 21.2 to 48.7 years (mean 28.8; SD 8.9 years), were enrolled in the study. Inclusion criteria were normal corneas (no corneal scarring, corneal pathology or prior corneal surgery), assessed by slit lamp examination and videokeratometry, and corneal astigmatism of not more than 2.50 D. Contact lens wearers were enrolled only if they had taken their lenses out for 12 h before the experiment. All subjects had been informed about the experiment in detail and had signed the consent document in compliance with the Declaration of Helsinki before the experiment.

Materials

All tonometric measurements were carried out with a rebound tonometer (ICare; Finland Oy). The CLs used were

Table 1 Properties of the CLs used in the study (the manufacturer would not provide thickness data for positive CLs).

Material	Etafilcon A
BOZR (mm)	8.70
TD (mm)	14.0
Fv'	+2.00 and +6.00
Modulus (MPa)	0.26
Dk/t ($\times 10^{-9}$)	40
Water content (%)	58
Central thickness (−3.00 D) (mm)	0.084
FDA Group	IV

bi-weekly replacement hydrogel (Acuvue 2™). The properties of the contact lens are reported in Table 1. Two different spherical powers were used: +2.00 D and +6.00 D.

Procedure

To evaluate the effect of power on the measurement of IOP, a repeated measurements design was used. Four measures of IOP were taken on the right eye of each subject. The first measurement (RT1) and the last measurement (RT4) were taken without CLs. The second and third measurements were performed over the two different powers of the CLs. In order to prevent a possible effect on IOP of the repetition of the measurement⁴³ or the insertion and removal of CLs,⁴⁴ each subject was assigned randomly to one of two different sequences (Table 2). In order to control accommodation, that might influence the measurement of IOP during experiments,^{45–46} the left eye (corrected with CLs for any hyperopic defect) viewed a distance target (6/24 or 0.6 logMAR).

One investigator assigned each subject randomly to one experimental condition and fitted all CLs to each subject. A second investigator, experienced in rebound tonometry, performed all IOP measurements on each subject for all conditions in order to reduce between-observer bias. He was blind to which kind of CLs had been fitted. Rebound tonometry was undertaken in the usual manner as recommended by the manufacturer. Two readings were obtained and averaged.

A third investigator checked the position of the rebound tonometer probe on the cornea during the measurement. If the position was incorrect, the measurement was rejected.

Table 2 The two sequences of measurements performed on the right eye. Key: RT1: first measurement without CL. +2: measurement with hydrogel +2.00 D. +6: measurement with hydrogel +6.00 D. RT4: second measurement without CL.

First sequence	Second sequence
RT1	RT1
+2	+6
+6	+2
RT4	RT4

This control was performed because it has been demonstrated that the location of the tonometer on the cornea can affect the measurement of IOP^{47–48} even though a recent study showed that the rebound tonometer appears insensitive to misalignments.⁴⁹

After the measurement the third investigator read the measure on the display of the tonometer. Measurements of IOP that the instrument indicated were unreliable were discarded. Thus the measurements were repeated up to the moment the third investigator had two valid readings. The number of measures required to achieve two valid readings was recorded. To reduce between observer and fitter bias, the three investigators remained the same for the entire experiment. There was an interval of five minutes between each repeated measure. A new disposable probe was used for each subject. All measurements were taken between 1.00 and 3.00 pm in order to minimize the effect of diurnal variation of IOP on the results.

Before the IOP measurements, a corneal topographic map as well as a pachymetric map of each cornea was taken by a Scheimpflug camera system (Sirius acquiring system; CSO, Florence, Italy) in order to evaluate a possible effect of corneal thickness and curvature on tonometric measurement.

Analysis

Data were analyzed using STATISTICA (StatSoft Inc., Tulsa, OK, USA) V.6.0 for Windows. Descriptive data were expressed in mean \pm standard deviation.

The Kolmogorov–Smirnov test was used to evaluate the results for a normal distribution of IOP, and corneal parameters data. All the statistical processing used to analyze the comparison between the measurements with and without CLs was performed using a value for the latter (RT) that was the mean of the first (RT1) and last measurements (RT4). The strength of the relationship between IOP measurements without CLs and with the two powers of CLs was evaluated using a correlation analysis (r of Pearson). A Bland–Altman plot was used to assess the difference in IOP reading with and without the two powers of CLs as a function of IOP value. A Student's paired t test for repeated measurement was applied in order to evaluate the differences between the measurements obtained without CLs and with each positive CL. Considering the sample size, the statistical powers of the significant comparisons of paired t test +2 and RT and +6 and RT were 0.987 and 0.965 respectively.

Any possible relationship between corneal parameters (thickness, curvature, asphericity) and the measurement of IOP over positive CLs was evaluated using a correlation analysis (r of Pearson) between every corneal parameter measure and the difference in IOP measurement with and without the CLs.

Results

Mean corneal astigmatism of the subjects' right eyes was -0.73 ± 0.37 D (range $-0.15/-1.60$ D). Twenty right eyes had with the rule astigmatism (steepest corneal meridian $90^\circ \pm 20^\circ$), three had against the rule astigmatism (steepest corneal meridian $180^\circ \pm 20^\circ$) and three had oblique

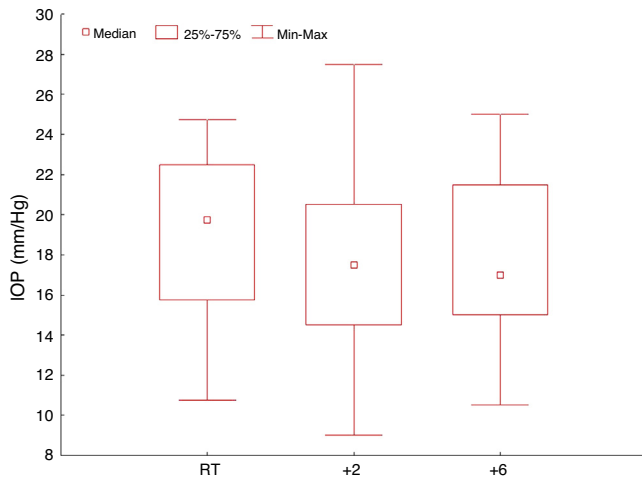


Figure 1 IOP measured over the two powers of CL, +2.00 (+2), and +6.00 (+6) and without CL (RT).

astigmatism (steepest meridian between 21° and 69° or 111° and 159°). The right eye central corneal thickness and the corneal thickness at the pupil centre was 540 ± 32 μm and 542 ± 32 μm respectively.

Mean spherical equivalent refraction of the subjects' right eyes was -2.10 ± 2.28 D (range -0.75/-7.13 D).

Mean of intraocular pressure without CLs and with +2.00 D and +6.00 D was 19.0 ± 4.1 mmHg (range: 9.0-27.5), 17.6 ± 4.6 mmHg (range: 10.5-25.0) and 17.8 ± 4.1 mmHg (range: 10.8-24.8) respectively (Fig. 1).

Every single distribution of the measurements obtained in the several conditions was normal. The correlations between IOP measurements without CLs and with the positive CLs were > 0.9 (*p* < 0.05 in all cases).

The Bland-Altman plots for the comparison between the measurement with +2.00 D CL and without CL (RT) and the measurement with +6.00 D CL and without CL respectively are shown in Figs. 2 and 3. The first Bland-Altman plot (Fig. 2) shows that there is no proportional bias: no significant trend was detected for differences between +2.00 D and RT measurements as a function of their mean value (*r* = 0.30, *p* = 0.141). The second Bland-Altman plot (Fig. 3)

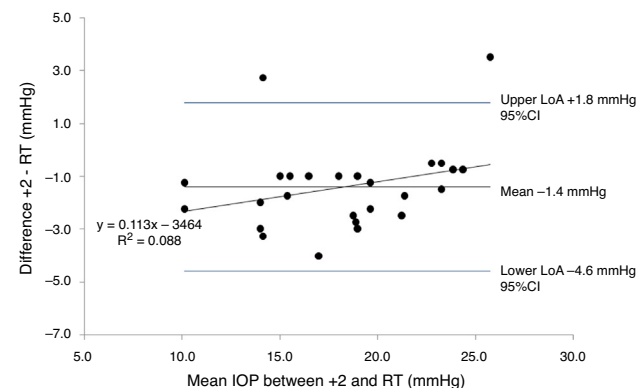


Figure 2 Bland-Altman plot of the differences between +2.00 D and RT (without CL) plotted against mean of the two measures. Limits of agreement are calculated as mean difference ± 1.96 SD of differences.

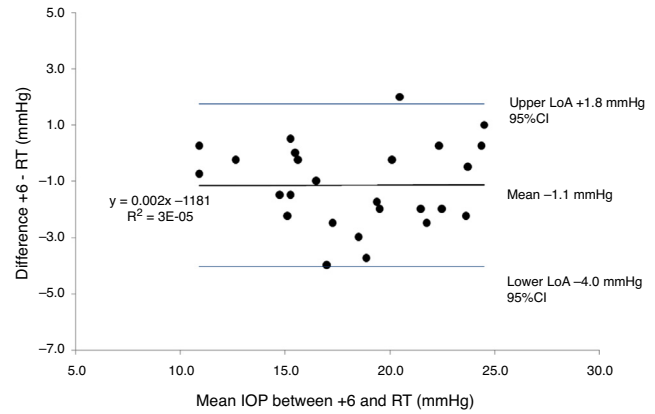


Figure 3 Bland-Altman plot of the differences between +6.00 D and RT (without CL) plotted against mean of the two measures. Limits of agreement are calculated as mean difference ± 1.96 SD of differences.

for the +6.00 D and RT measurements gave a similar result, mean value (*r* = 0.006, *p* = 0.98).

Table 3 gives the paired-samples t-test between the measurements with and without CLs. All the comparisons between the measurements without CLs and the measurements with the positive CLs were significant. The comparison between measures obtained with the +2.00 D and +6.00 D CLs was not significant.

In order to evaluate if corneal parameters such as thickness, curvature or asphericity were affecting the difference in IOP measurement with and without CLs, a coefficient of correlation was calculated. None of these parameters correlated with the difference between IOP values obtained with +2.00 D and RT or +6.00 D and RT.

Discussion

IOP measurement with a rebound tonometer over positive hydrogel CLs provides statistically significant lower values than the measurement without CLs. The decrease is not proportional to the increase in refractive power of the CL. Despite the fact the difference is statistically significant, from a clinical point of view this difference is minimal because it is almost at the cut off value of more than 1.5 mmHg that is considered relevant.⁵⁰

Although the rebound tonometer is among the most recent instruments used today, it is gaining a relative acceptance especially for the simplicity of the procedure and that topical anaesthesia and fluorescein are not required. The results are reproducible and reasonably accurate.³²⁻³³ Furthermore it can be used in challenging patients such

Table 3 Paired comparisons between the measurements in the different conditions with and without CLs.

Comparison	<i>t</i>	<i>p</i>
+2 and +6	-0.77	0.45
+2 and RT	-4.37	0.0002
+6 and RT	-3.95	0.0005

as children^{51–52} or the disabled. It is suitable for reclined patients, domiciliary visits and self-measurement.⁵³

It has been shown that with the rebound tonometer it is possible to measure IOP over soft CLs, either hydrogel (etafilcon A) or silicone hydrogel (senofilcon A), with good accuracy.⁴¹ In this study it was shown that IOP measurements were lower than those without CLs. The difference was not statistically significant with silicone hydrogel CLs. The differences in IOP were statistically significant for hydrogel CLs. The underestimation of IOP was greater for power +2.00D compared to CLs of negative power.

Our results appear to conflict with previous studies where the tonometry measurement was taken using conventional applanation tonometers, especially the air puff type, where positive soft CLs contribute to an increase in the value of IOP.^{7,20–23,54–56} The results from tonometry can be influenced by the characteristics of the patient's cornea such as corneal thickness^{57–58} corneal curvature⁵⁹ and corneal biomechanical factors.⁶⁰ True IOP will be overestimated in eyes with thick corneas, a steep corneal curvature and high corneal hysteresis. However, most researchers have considered the effect of tonometry based on applanation principles. Regarding the rebound tonometer, Chui et al.,³⁶ have found that the result is affected by biomechanical corneal properties but not corneal thickness. Jorge et al.,⁶¹ found that although corneal thickness can play a role in rebound tonometry, individual physiological variations of biomechanical corneal properties such as the elastic and viscoelastic responses, may be more relevant factors.

In a recent cross-sectional study,⁴² the effect of plano power lotrafilcon A contact lenses in situ on IOP measurement from three portable tonometers, including ICare, was assessed in young healthy subjects. A statistically significant overestimation of 1.00 mmHg was found between IOP measurements obtained with the rebound tonometer with and without CLs. This result could be attributed to the higher modulus of lotrafilcon A which should offer more resistance to the deformation than CLs in senofilcon A (used in the previous study⁴¹), and etafilcon A (used in the previous and present studies). A similar increment in IOP was found by Anton et al.,²⁵ when measuring IOP with a rebound tonometer over a silicone hydrogel soft CL (balafilcon A) characterized by a water content of 36%, back vertex power of plano and a central thickness of 0.07 mm.

The decrement in IOP found in the present study could be attributed to low resistance to deformation produced by etafilcon A⁶² a hydrogel characterized by high water content. In this study, we have had the opportunity to compare the effect on IOP induced by two CLs having positive powers, and significantly different thickness. The presence of the same trend in the change of IOP induced by the two CLs leads us to believe, in accordance with Chui et al.,³⁶ that the thickness at the centre of the cornea, or cornea together with the CL, does not affect the value of IOP assessed with a rebound tonometer.

Conclusion

In conclusion, the measurement of IOP while positive power CLs having a water content of 58%, such as those in etafilcon A, are worn, tends to give lower values than those

obtained without CLs. This occurs with both +2.00D and +6.00D CLs. Eye care practitioners should keep this in mind when analyzing IOP values or remove positive CLs before performing rebound tonometry measurements.

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Conflict of interest

The authors have no conflicts of interest to declare.

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References

1. Resnikoff S, Pascolini D, Etya'ale D, et al. Global data on visual impairment in the year 2002. *Bull World Health Organ.* 2004;82:844–851.
2. Weinreb RN, Brandt J, Garway-Heath T, Medeiros FA. *Intraocular pressure.* Amsterdam: Kugler Publications; 2007.
3. Lupelli L, Zeri F. Tonometria senza anestesia farmacologica della cornea. Una rassegna aggiornata. *Atti Fondaz Giorgio Ronchi.* 1995;2:189–212.
4. Villani S. Un nuovo procedimento di tonometria. *Atti Fondaz Giorgio Ronchi.* 1972;27:745 [letter].
5. De Luca TJ, Forgacs LS, Skolnick SD. The use of Bausch & Lomb Soflens in tonometry. *J Am Optom Assoc.* 1974;45:1028–1038.
6. Scibilia GD, Ehlers WH, Donshik PC. The effects of therapeutic contact lenses on intraocular pressure measurement. *CLAO J.* 1996;22:262–265.
7. Kreda SH. Applanation tonometry in contact lens practice. *J Am Optom Assoc.* 1987;58:208–214.
8. Lim L, Ng TP, Tan DTH. Accurate intraocular pressure measurement in contact lens wearers with normal pressure. *CLAO J.* 1997;23:130–133.
9. Allen RJ, De Wit D, Saleh GM. Applanation tonometry in silicone hydrogel contact lens wearers. *Cont Lens Anterior Eye.* 2007;30:267–269.
10. Zeri F, Lupelli L, Formichella P, Masci C, Fletcher R. Goldmann applanation tonometry over daily disposable contact lens: accuracy and safety of procedure. *Cont Lens Anterior Eye.* 2007;30:233–238.
11. Firat PG, Cankaya C, Doganay S, et al. The influence of soft contact lenses on the intraocular pressure measurement. *Eye.* 2012;26:278–282.
12. Gomes BAF, Turiel P, Cavalcanti RS, Moraes HV, Santhiago MR. The accuracy of Goldmann applanation tonometry over silicone hydrogel contact lenses in patients with glaucoma. *Cont Lens Anterior Eye.* 2014;37:297–299.
13. Meyer RF, Stanifer RM, Bobb KC. Mackay-Marg tonometry over therapeutic soft contact lenses. *Am J Ophthalmol.* 1978;86:19–23.
14. Panek WC, Boothe WA, Lee DA, Zemplyeni E, Pettit TH. Intraocular pressure measurement with the Tono-Pen through soft contact lenses. *Am J Ophthalmol.* 1990;109:62–65.

15. Khan JA, LaGreca BA. Tono-Pen estimation of intraocular pressure through bandage contact lenses. *Am J Ophthalmol*. 1989;108:422–425.
16. Janoff LE. Intraocular pressure measurement with the tonopen II over a disposable soft lens. *ICCL*. 1991;18:246–249.
17. Schornack M, Rice M, Hodge D, Tonopen XL. Assessment of intraocular pressure through silicone hydrogel contact lenses. *Eye Contact Lens*. 2012;38:270–273.
18. Rubenstein JB, Deutsch TA. Pneumatometry through bandage contact lenses. *Adv Ophthalmol*. 1985;103:1660–1661.
19. Krieglstein GK, Waller WK, Reimers H, Langham ME. Augeninnendruckmessung auf weichen kontaktlinsen. *Graefes Arch Clin Exp Ophthalmol*. 1976;199:223–229.
20. McMonnies CW. Non-contact tonometry through soft contact lenses. *Am J Optom Physiol Opt*. 1986;63:948–951.
21. Insler MS, Robbins RG. Intraocular pressure by noncontact tonometry with and without contact lenses. *Adv Ophthalmol*. 1987;105:1358–1359.
22. Patel S, Illahi W. Non-contact tonometry over soft contact lenses: effect of contact lens power on the measurement of intra-ocular pressure. *Cont Lens Anterior Eye*. 2004;27:33–37.
23. Patel S, Stevenson G. Influence of lens material and intraocular pressure on the outcome of non-contact tonometry over soft contact lenses. *Cont Lens Anterior Eye*. 2009;32:68–72.
24. Liu YC, Huang JY, Wang IJ, Hu FR, Hou YC. Intraocular pressure measurement with the noncontact tonometer through soft contact lenses. *J Glaucoma*. 2011;20:179–182.
25. Anton A, Neuburger M, Böhringer D, Jordan JF. Comparative measurement of intraocular pressure by Icare tonometry and airpuff tonometry in healthy subjects and patients wearing therapeutic soft contact lenses. *Graefes Arch Clin Exp Ophthalmol*. 2013;251:1791–1795.
26. Sapkota K, Franco S, Lira M. Intraocular pressure measurement with ocular response analyzer over soft contact lens. *Cont Lens Anterior Eye*. 2014;37:415–419.
27. Nosch DS, Duddek AP, Herrmann D, Stuhmann OM. Dynamic contour tonometry over a thin daily disposable hydrogel contact lens. *Cont Lens Anterior Eye*. 2010;33:219–224.
28. Gogniat F, Steinegger D, Nosch DS, Joos R, Goldschmidt M. The accuracy of dynamic contour tonometry over soft contact lenses. *Optom Vis Sci*. 2013;90:125–130.
29. Lam AKC, Tse JSH. Dynamic contour tonometry over silicone hydrogel contact lens. *J Optom*. 2014;7:91–99.
30. Dekking HM, Coster HD. Dynamic tonometry. *Ophthalmologica*. 1967;154:59–74.
31. De Moraes CGV, Prata TS, Liebmann J, Ritch R. Modalities of tonometry and their accuracy with respect to corneal thickness and irregularities. *J Optom*. 2008;1:43–49.
32. Abraham LM, Epasinghe NC, Selva D, Casson R. Comparison of the Icare rebound tonometer with the Goldmann applanation tonometer by experienced and inexperienced tonometrists. *Eye*. 2008;22:503–506.
33. Martinez-de-la-Casa JM, Garcia-Feijoo J, Castillo A, Garcia-Sanchez J. Reproducibility and clinical evaluation of rebound tonometry. *Invest Ophthalmol Vis Sci*. 2005;46:4578–4580.
34. Van der Jagt LH, Jansonius NM. Three portable tonometers, the TGDc-01, the ICARE and the Tonopen XL, compared with each other and with Goldmann applanation tonometry. *Ophthalmic Physiol Opt*. 2005;25:429–435.
35. Nakamura M, Darhad U, Tatsumi Y, et al. Agreement of rebound tonometer in measuring intraocular pressure with three types of applanation tonometers. *Am J Ophthalmol*. 2006;142:332–334.
36. Chui WS, Lam A, Chen D, Chiu R. The influence of corneal properties on rebound tonometry. *Ophthalmology*. 2008;115:80–84.
37. Johannesson G, Hallberg P, Eklund A, Lindén C. Pascal, Icare and Goldmann applanation tonometry – a comparative study. *Acta Ophthalmol*. 2008;86:614–621.
38. Brusini P, Salvétat ML, Zeppieri M, Tosoni C, Parisi L. Comparison of Icare tonometer with Goldmann applanation tonometer in glaucoma patients. *J Glaucoma*. 2006;15:213–217.
39. Fernandes P, Diaz-Rey JA, Queiros A, Gonzalez-Mejome JM, Jorge J. Comparison of the Icare rebound tonometer with the Goldmann tonometer in a normal population. *Ophthalmic Physiol Opt*. 2005;25:436–440.
40. Salvétat ML, M Zeppieri M, Miani F, Tosoni C, Parisi L, Brusini P. Comparison of Icare tonometer and Goldmann applanation tonometry in normal corneas and in eyes with automated lamellar and penetrating keratoplasty. *Eye*. 2011;25:642–650.
41. Zeri F, Calcatelli P, Donini B, Lupelli L, Zarrilli L, Swann PG. The effect of hydrogel and silicone hydrogel contact lenses on the measurement of intraocular pressure with rebound tonometry. *Cont Lens Anterior Eye*. 2011;34:260–265.
42. Garcia-Resua C, Garcia-Montero S, Pena-Verdeal H, Gilino J, Yebra-Pimentel E, Giráldez MJ. Effect of lotrafilcon A silicone hydrogel contact lens on intraocular pressure measurement. *Optom Rep*. 2014;4:7–10.
43. Motolko MA, Feldman F, Hyde M, Hudy D. Sources of variability in the results of applanation tonometry. *Can J Ophthalmol*. 1982;17:93–95.
44. Khan JA, Graham CE. Effect of contact lens removal or displacement on intraocular pressure. *Adv Ophthalmol*. 1991;109:825–828.
45. Mauger RR, Likens CP, Applebaum M. Effect of accommodation and repeated applanation tonometry on intraocular pressure. *Am J Optom Physiol Opt*. 1984;61:28–30.
46. Read SA, Collins MJ, Becher H, et al. Changes in intraocular pressure and ocular pulse amplitude with accommodation. *Br J Ophthalmol*. 2010;94:332–335.
47. Queirós A, González-Mejome JM, Fernandes P, et al. Technical note: a comparison of central and peripheral intraocular pressure using rebound tonometry. *Ophthalmic Physiol Opt*. 2007;27:506–511.
48. González-Mejome JM, Jorge J, Queirós A, et al. Age differences in central and peripheral intraocular pressure using a rebound tonometer. *Br J Ophthalmol*. 2006;90:1495–1500.
49. Beasley IG, Laughton DS, Coldrick BJ, Drew TE, Sallah M, Davies LN. Does rebound tonometry probe misalignment modify intraocular pressure measurements in human eyes? *J Ophthalmol*. 2013;79:1084.
50. Danesh-Meyer HV, Papchenko T, Tan YW, Gamble GD. Medically controlled glaucoma patients show greater increase in intraocular pressure than surgically controlled patients with the water drinking test. *Ophthalmology*. 2008;115:1566–1570.
51. Sahin A, Basmak H, Niyaz L, Yildirim N. Reproducibility and tolerability of the Icare rebound tonometer in school children. *J Glaucoma*. 2007;16:185–188.
52. Flemmons MS, Hsiao YC, Dzau J, Asrani S, Jones S, Freedman SF. Icare rebound tonometry in children with known and suspected glaucoma. *J AAPOS*. 2011;15:153–157.
53. Flemmons MS, Hsiao YC, Dzau J, Asrani S, Jones S, Freedman SF. Home tonometry for management of pediatric glaucoma. *Am J Ophthalmol*. 2011;152:470–478.
54. Draeger J. Applanationstonometrie auf kontaktlinsen mit hohem wassergehalt Problem ergebnisse und korrekturfaktoren. *Klin Monatsbl Augenheilkd*. 1980;176:38–43.
55. Schollmayer P, Hawlina M. Effect of soft contact lenses on the measurement of intraocular pressure with non-contact pneumotonometry. *Klin Monatsbl Augenheilkd*. 2003;220:840–842.
56. Cobbe C, Tosi R, Baravelli S, et al. Determinazione della tensione oculare mediante pneumotonometro in portatori di lac morbide. *Boll Ocul*. 1990;69:1203–1207.
57. Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. *Surv Ophthalmol*. 2000;44:367–408.

58. Ehlers N, Hjortdal J. Corneal thickness: measurement and implications. *Exp Eye Res.* 2004;78:543–548.
59. Whitaker MM, Stein R. Source of error with use of Goldmann-type tonometers. *Surv Ophthalmol.* 1993;38:1–30.
60. Liu J, Roberts CJ. Influence of corneal biomechanical properties on intraocular pressure measurement: quantitative analysis. *J Cataract Refract Surg.* 2005;31:146–155.
61. Jorge JMM, Gonzalez-Méjome JM, Queiros A, Fernandes P, Parafita MA. Correlations between corneal biomechanical properties measured with the ocular response analyzer and ICare rebound tonometry. *J Glaucoma.* 2008;17:442–448.
62. Jones L, Subbaraman L, Rogers R, Dumbleton K. Surface treatment, wetting and modulus of silicone hydrogels. *Optician.* 2006;232:28–34.