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Research Article

Comparison of Intraocular Pressure Measured with AccuPen and Goldmann in a Glaucoma Consultation

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Abstract

Introduction: Intraocular pressure (IOP) measurement with Goldmann applanation tonometry (GAT) is currently considered the gold standard. AccuPen tonometry is a portable and rapid method, but there is no local evidence supporting its reliability.

Objective: To determine whether IOP measurements obtained with AccuPen are comparable to those obtained with Goldmann tonometry.

Materials and Methods: A prospective comparative study including 114 patients (228 eyes) measured with both AccuPen and Goldmann tonometry. Data collected included age, sex, glaucoma diagnosis (yes/no), and central corneal thickness (CCT). Descriptive and inferential statistics were applied, with a significance level of 5% to compare differences.

Results: 69.3% of participants were female, with a mean age of 63.4 years (SD = 13.9), ranging from 17 to 87 years. Goldmann tonometry: 17.6 ± 7.0 mmHg (SD = 6.95) (range: 6–60 mmHg). AccuPen tonometry: 18.6 ± 7.2 mmHg (SD = 7.15) (range: 5–57 mmHg). The mean difference between methods was -0.99 mmHg (SD = 3.16) (range: -12 to 11 mmHg), which was statistically significant ($p < 0.001$), with a medium effect size (D = -0.3125). 56.1% of cases: Goldmann > AccuPen, 30.3% of cases: AccuPen > Goldmann, 13.6% of cases: Identical measurements. Glaucoma diagnosis was present in 53.5% of cases. The mean central corneal thickness was 545.1 µm (SD = 40.7) (range: 333–737 µm). Bland-Altman analysis showed that all differences were within the [-6, +6] mmHg range, with 89.9% within [-5, +5], 84.6% within [-4, +4], and 77.1% within [-3, +3]. Sex, glaucoma diagnosis, and CCT were analyzed as differentiation factors, with no statistically significant differences observed.

Conclusions: There is a significant difference between both methods, with only a small fraction of identical measurements, making them non-interchangeable. However, the majority of differences fell within ± 3 mmHg, suggesting that AccuPen could be a reasonable alternative for screening and in cases where Goldmann tonometry is not feasible.

Keywords: AccuPen; Goldmann; Tonometry; Glaucoma

Introduction

Glaucoma is the second leading cause of blindness worldwide after cataracts and the primary cause of irreversible blindness [1-3]. It is estimated that by 2040, approximately 111.8 million people worldwide will be affected [1,4,5]. Due to its asymptomatic nature, underdiagnosis, limited access to treatment, and healthcare services pose significant challenges [1,5]. Intraocular pressure (IOP) plays a crucial role in monitoring, management, and determining therapeutic targets [6,7].

Goldmann applanation tonometry (GAT) is considered the gold standard [8], requiring a trained operator, more time, and greater patient cooperation. AccuPen tonometry is a portable, rapid, and easy-to-use method; however, no comparative studies have demonstrated its reliability against Goldmann tonometry in our population [9,10].

The primary objective of this study is to determine whether IOP measurements obtained with AccuPen are interchangeable or comparable with those obtained using Goldmann applanation tonometry (GAT).

Materials and Methods

Our study design was prospective and comparative. The sample size consisted of 114 patients (228 eyes), including patients referred for suspected glaucoma to the glaucoma clinic at the Hospital Clínico San Borja Arriarán in Santiago, Chile, who had their intraocular pressure (IOP) measured using Accupen and Goldmann tonometry (GT). Variables recorded included age, sex, glaucoma diagnoses (yes/no), and corneal pachymetry using ultrasound. Informed consent was obtained.

To determine the study objective, we analyzed the difference between both measurements and the magnitude of this difference, as well as its correlation with sex, glaucoma diagnosis, and pachymetry.

Descriptive and inferential statistics were used, with a significance level of 5%. For the comparison between tests, a paired Student's t-test was applied. The null hypothesis was that both means are equal (H_0: μ_G - μ_A = 0), and the alternative hypothesis was that they are different (H_1: μ_G - μ_A ≠ 0).

Results

Of the total 114 patients evaluated, 69.3% were female, and the mean age of the sample was 63.4 years (SD = 13.9) (range 17-87 years). 53.5% of the patients had a diagnosis of glaucoma, and the average pachymetry was 545.1 ± 40.7 microns, with a range between 333 and 737 (see Table I).

Descriptive Statistics		
Variable	**Frequency**	**Percentage**
Sex	Female: 158 Male: 70	Female: 69.3% Male: 30.7%
Age	Mean (SD): 63.4 (13.9) Range: 17–87	
Goldmann	Mean (SD): 17.6 (6.95) Range: 6–60	
Accupen	Mean (SD): 18.6 (7.15) Range: 5–57	
Difference	Mean (SD): -0.99 (3.16)	
G > A	128	56.1%
G = A	31	13.6%
G < A	69	30.3%
Diagnosis	Glaucomatous: 122 Non-glaucomatous: 106	Glaucomatous: 53.5% Non-glaucomatous: 46.5%
Pachymetry	Mean (SD): 545.1 (40.7) Range: 333–737	

Table I: Sociodemographic Profile.

Regarding tonometric measurements, the average IOP measured with Goldmann tonometry (GT) was 17.6 ± 7.0 mmHg (range 6-60), while the Accupen measurement was 18.6 ± 7.2 mmHg (range 5-57). The difference between both measurements was calculated, yielding an average of -0.99 ± 3.2 mmHg (range -12 to 11). Upon classifying these results, 56.1% of the measurements (128 cases) showed Goldmann values higher than Accupen, while 30.3% (69 cases) showed Accupen values higher than Goldmann. 13.6% (31 cases) had identical measurements.

Difference between measurements

The estimated mean difference was -0.99 mmHg, which was statistically significant ($p<0.001$), accompanied by a medium

effect size (Cohen's d = -0.3125) and a confidence interval ranging from -1.39 to -0.57 mmHg (see Table II). Figures 1 and 2 show the distribution of measurements, differences, and density.

Paired Samples T-Test

Goldmann Mea	Goldmann SD	Accupen Mean	Accupen SD	Difference	95% CI	t	df	p	Cohen's d
17.5903	6.9565	18.5771	7.153	-0.9868	-1.39 ; -0.57	-5	227	< .001	-0.3125

Table II: Classification of Diagnostic Tests. Complete sample.

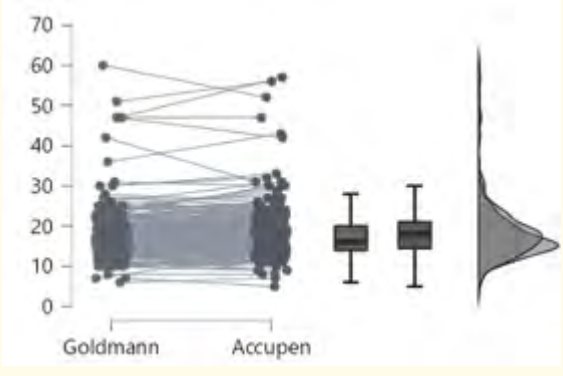

Figure 1: Comparison of tonometries.

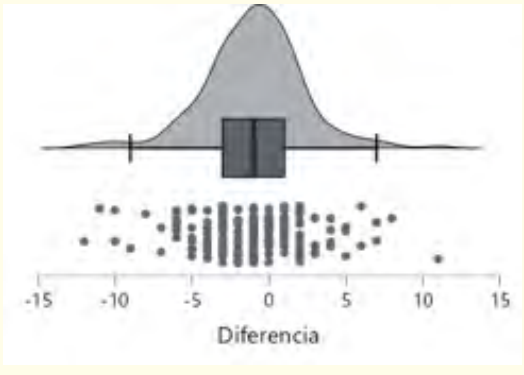

Figure 2: Density for Difference.

Additionally, Bland-Altman plots were presented with 95% confidence limits to assess the uniformity and consistency of the results. It was observed that nearly all the differences between the tonometry methods were within the confidence limits, located between [-6, +6] (see Figure 3a). Similarly, 89.9% of the differences were within [-5, +5] (see Figure 3b), 84.6% were within [-4, +4] (see Figure 3c), and 77.1% were within [-3, +3] (see Figure 3d).

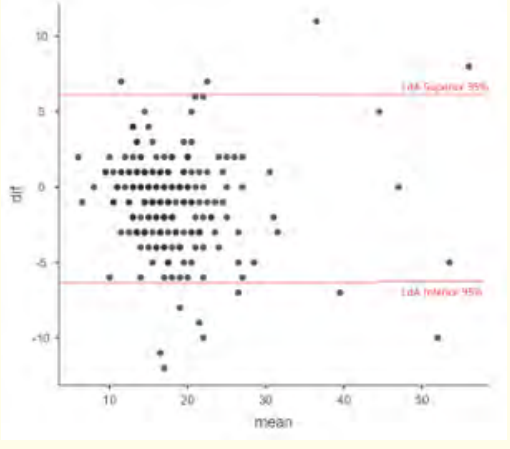

Figure 3a: Bland-Altman plot [-6, +6].

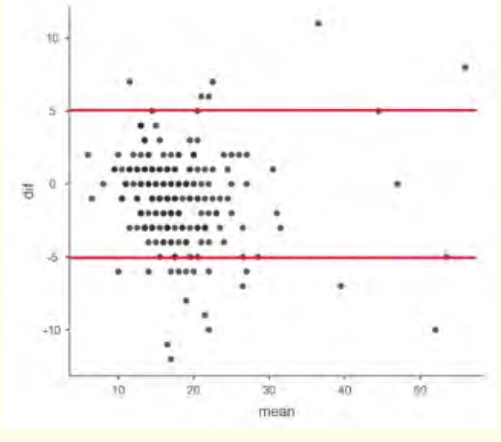

Figure 3b: Bland-Altman plot [-5, +5].

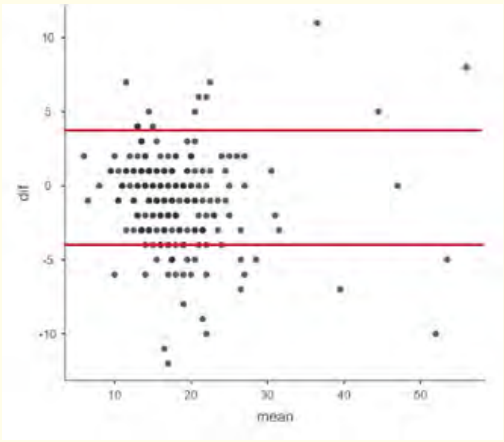

Figure 3c: Bland-Altman plot [-4, +4].

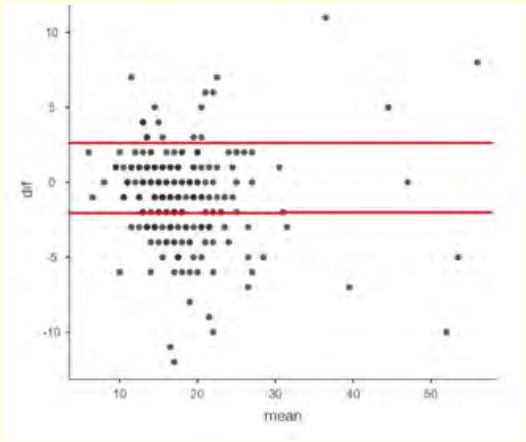

Figure 3d: Bland-Altman plot [-3, +3].

Tonometry differences between genders

An independent samples t-test was performed, considering gender as a differentiating factor. The result did not show significant differences (p = 0.56), meaning that for women, the estimated difference was -0.63 ± 6.4 mmHg, and for men, it was -0.79 ± 3.7 mmHg (see Table III and Figure 4).

Tonometry differences between glaucomatous and non-glaucomatous patients

An independent samples t-test was performed, considering being diagnosed or not as a differentiating factor. The result did not show statistically significant differences (p = 0.33), meaning that for non-glaucomatous patients, the estimated difference was -1.20 ± 2.3 mmHg, and for glaucomatous patients, it was -0.22 ± 7.4 mmHg (see Table IV and Figure 5).

Statistic	Female (n = 158)	Male (n = 70)	T	p	D
Mean	-0.63	-0.79	-0.587	0.559	-0.088
Standard Deviation	6.36	3.66			
Minimum	-10	-12			
Maximum	8	11			

Table III: Comparisons of differences by sex. Independent Samples T-Test.

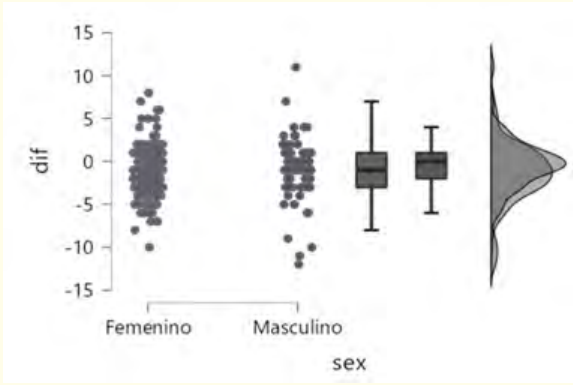

Figure 4: Comparison of differences by sex.

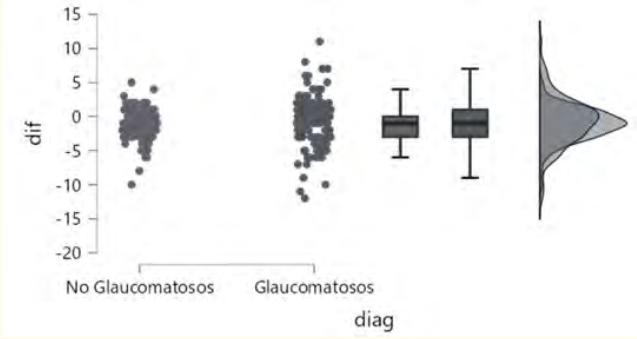

Figure 5: Comparison of differences by diagnosis.

Descriptive Statistics	dif	Non Sleepers (n = 106)	Sleepers (n = 127)	T	p	D
Mean		-1.20	-0.22	-0.971	0.333	-0.127
Standard Deviation		2.34	7.41			
Minimum		-10	-12			
Maximum		5	11			

Table IV: Comparisons of differences by diagnosed individuals. Independent Samples T-Test.

Correlations between pachymetry and tonometry measurements

For the relationship between pachymetry and Goldmann tonometry, the correlation coefficient was r = 0.01 (p = 0.43), indicating no correlation between the two measurements (Figure 6a). For the relationship between pachymetry and Accupen tonometry, r = -0.02 (p = 0.62), meaning no correlation between the two readings (Figure 6b). For the relationship between pachymetry and the difference between tonometries, r = 0.07 (p = 0.14), which was not statistically significant (Figure 6c).

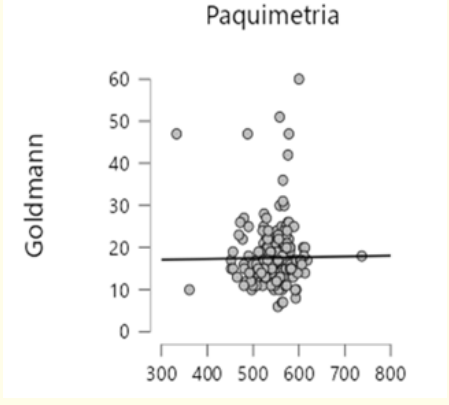

Figure 6a: Scatter plots. Goldmann vs. Pachymetry.

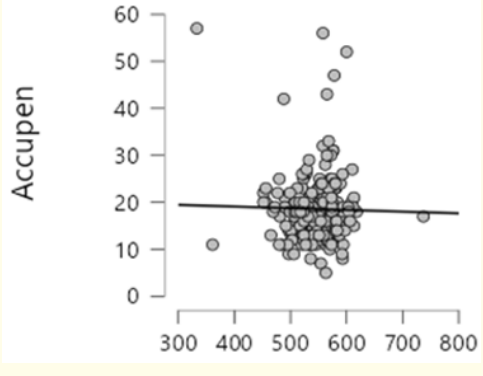

Figure 6b: Scatter plots. Accupen vs. Pachymetry.

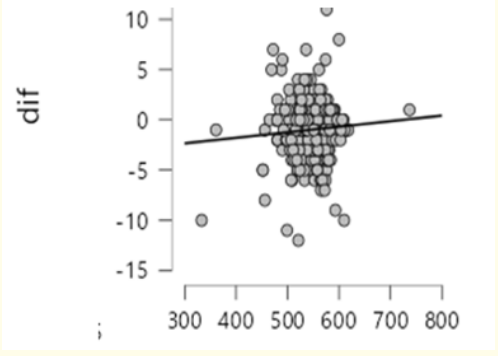

Figure 6c: Scatter plots. Difference vs. Pachymetry.

Discussion

Intraocular pressure (IOP) measurement is one of the cornerstones of glaucoma monitoring and diagnosis, making it a fundamental pillar in ophthalmic evaluation, with GAT being the gold standard for this purpose [1,8,10]. However, we must consider its limitations, such as being fixed to the slit lamp or the difficulties encountered when trying to obtain a good view of the corneal rings during measurement in certain patients [12]. Accupen, on the other hand, is an easy-to-use method, requires less training, and can adapt to various patient conditions.

There are studies comparing GAT with newer measuring methods similar to Accupen, but we have not found a direct comparison of Accupen and GAT conducted in human subjects, although comparisons have been made in veterinary medicine, where similar results have been found between contact tonometers, but not in comparison to the gold standard [9].

In our study, we found a significant difference between Accupen and GAT, which aligns with the findings of Frenkel., *et al.* [13], who observed an underestimation with the tone-pen, a method similar to Accupen. On the other hand, Kato's study found no significant difference [9], but observed a large variation when compared to GAT, which is crucial because underestimating IOP could lead to

the underdiagnosis or delayed diagnosis of glaucoma, a situation that is detrimental and critical for proper disease control [7].

The difference in IOP measurements we found is slightly larger than what has been reported in similar studies [9,10,13], indicating that we should consider up to a 3 mmHg underestimation in some patients. This emphasizes the importance of validating new alternatives for IOP measurement in ophthalmological patient management.

In our sample, we found no significant differences in tonometry results when classified by sex, which is consistent with the reviewed literature [1,4,5,7,10,13], where differences between the two tonometers in both male and female groups were less than 1 mmHg.

When patients were grouped by glaucoma diagnosis, we found that this factor did not significantly affect the measurements, although in the glaucoma group, the dispersion was slightly smaller than in the non-glaucoma group. We did not find specific references in the literature regarding this, but we can hypothesize that this slight difference may be attributed to the presence of other conditions affecting corneal mechanics, which may alter measurements in a secondary manner, and were not recorded in this study.

Considering pachymetry as a potential source of error in the measurement, we observed no significant differences when comparing both tonometers, which is a topic of ongoing discussion. Various reports suggest that a thinner cornea may underestimate IOP measurements [10,14,16], while others indicate that corneal edema can alter readings, leading to underestimation [15,16]. Our study's findings suggest that pachymetry should not be considered as a value to adjust the final IOP measurement.

Conclusion

There is a significant difference between both methods, with only 13.6% of measurements being identical, making them non-interchangeable or comparable. However, 77.1% of the sample differences were within a range of ± 3 mmHg, which suggests that Accupen tonometry could be considered an acceptable alternative for screening purposes.

No significant differences were found when including the variables of sex or pachymetry, nor when the groups were separated by glaucoma diagnosis.

It is necessary to compare new tonometry technologies with the gold standard in order to optimize and simplify intraocular pressure measurements across all clinical scenarios, as there are many cases where Goldmann tonometry cannot be performed, and validated alternatives are needed for proper disease management.

Acknowledgments

None.

Conflict of Interests

The authors declare that there are no conflicts of interest.

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