



# Correlation of Goldmann Flattening Tonometry and Diaton Ballistic Principle Tonometry Measurements in Different Patient Groups

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## Abstract

**Purpose:** To compare intraocular pressure [IOP] between Goldmann leveling tonometry and Diaton ballistic principle tonometry over the eyelids in different patient groups. The use of Diaton as an alternative for mass population measurements for early diagnosis of glaucoma is being studied.

**Method:** 572 eyes of 572 patients were studied. The right eye was randomly assigned as the examination eye. The sample consisted of 54.5% women and 45.5% men of various ages. The vast majority of them are over 60 years old. The groups of patients studied are 22.7% glaucomatous, 24% with age-related macular degeneration, 21.8% diabetic and 43.8% are those who do not suffer from any of the above conditions and we called them healthy. Note that some suffered from glaucoma and diabetes and thus were counted in both groups. Intraocular pressure was measured in both eyes of all the above patients except for 2 of them in whom it was measured in only one eye. All eyes underwent IOP measurement with both Goldmann and Diaton. The values of the measurements were recorded. The Goldmann measurements were performed by the same physician without knowing the results of the Diaton measurements. As well as the measurements using the Diaton method was conducted by the same doctor and always in the same way. The measuring positions used during the examination with the Diaton are sitting or supine.

**Results:** A statistically strong correlation was found between the measurements of the 2 tonometers ( $p < 0.001$ ) with a deviation of up to 2 mmHg absolute value in 83.11% of the total sample. Also, there is a strong correlation between the deviations of the 2 instruments on the one hand and glaucoma on the other hand ( $p < 0.05$ ), but also a trend of correlation with increasing age of our sample ( $p < 0.05$ ). In the healthy group deviation greater than 5mmHg in absolute value is observed in 5% of the sample, while in the glaucomatics group in 15% of the sample. There is no correlation with parameters such as gender, glucose, IOP, thyroid eye disease, refraction and cataract ( $p > 0.05$ ).

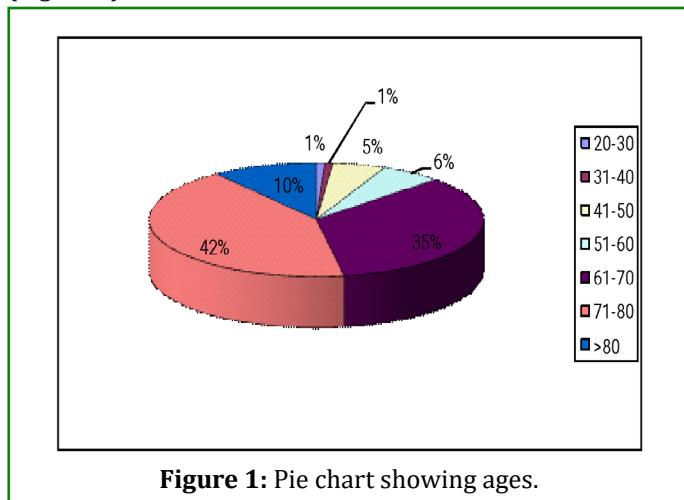
**Conclusion:** The Diaton ballistic principle tonometer can be used alternatively for measuring intraocular pressure over the eyelids in patients with recently operated eyes, after refractive surgery, with corneal trauma, with keratitis, with corneal epithelial apoptosis, with superficial ulcers and with large flaps. It can also be used to measure EOP easily in children. Its utility is great since due to its portability, intraocular pressure can be measured in cataract patients.

**Indexing Words:** Glaucoma; EOP; Ballistic Principle Tonometry; Diaton Tonometer; Over-Eyelid Tonometry

**Keywords:** Glaucoma; IOP; Ballistic Principle Diaton Tonometry; Tonometry above the Upper Eyelid

## Introduction

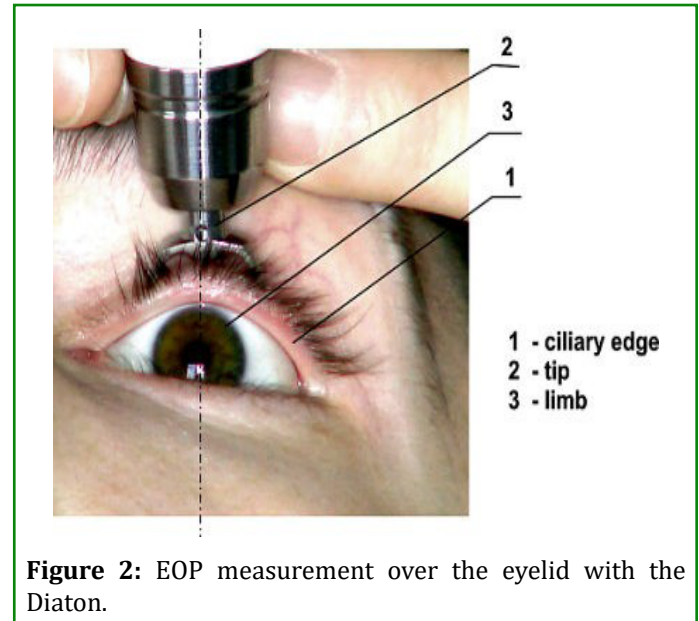
The most widely used method of measuring EEA is the Goldmann leveling tonometry. However, the accuracy of the measured values depends on factors such as the thickness of the cornea, its condition at the time of measurement, and the cooperation of the patient. It is also more difficult to use in children. Measuring intraocular pressure with the Diaton is a new method of measuring over the eyelids without the measured values depending on the above parameters. It uses the ballistic principle as its operating principle, where a plate of a certain weight is applied from a certain height to a surface of the eyelid which is flattened to a defined length of 1.5 mm. This impact of the plate on the eyelid causes the movement of the aqueous humour and the initiation of elastic forces which, by impacting on the sclera of the eye, are measured by the Diaton tonometer and give the measurement of the IOP in mmHg. There are 6 measurements and the instrument gives the average of these 6 measurements. The head of the tonometer is applied just above the free lid rim of the upper eyelid. The position of the head during measurement shall be horizontal and the pupil shall form an angle of 45° with the horizontal plane. The free eyelid rim should rest on the SFO (Figure 2).



**Figure 1:** Pie chart showing ages.

The Diaton contains a liquid which determines the correct measuring position. In a vertical position the audible signal of the instrument stops. This study was organized to compare the measured EOP between the Diaton ballistic principle tonometry and the Goldmann flattening tonometry, so that the new tonometer can be used in patients with corneal problems and in children where it is difficult or impossible

to use the Goldmann. Because the Diaton tonometer is small, lightweight and portable, ophthalmological equipment is not necessary to measure EOP, so it can also be used by general practitioners for population screening and early diagnosis of glaucoma (Figure 3).



**Figure 2:** EOP measurement over the eyelid with the Diaton.



**Figure 3:** The Diaton EEA measuring instrument.

## Method

This prospective study included 287 patients who visited the outpatient clinic of the General Hospital of St. Demetrios either for a routine examination or because they had diabetes or diagnosed glaucoma or EEG. No criteria were set to exclude any of the patients from the measurements and the study. All of the above patients underwent an eye examination (obtaining a complete ophthalmological and general history, obtaining visual acuity, refraction, orthoptic study, anterior segment examination, and EOP measurement with the 2 instruments, funduscopy). Of the patients enrolled in the study, 24% had EEG, 21.8% had diabetes, 22.7% had diagnosed glaucoma under treatment and 43.8% were healthy. The Goldmann measurement was performed by different physicians using anaesthetic (tetracaine hydrochloride), while the Diaton

measurements were performed by the same physician without the use of anaesthetic and always in the same way. Initially the EOP was measured with the Goldmann and then with the Diaton. The measurement positions during the Diaton examination were sitting and supine. The most appropriate measurement position with the new tonometer was supine, since the patients, even those who were first encountered with a tonometer, were more cooperative. Measurement values with the 2 tonometers were recorded. The measurements are presented as continuous values and their possible correlations were studied with the Pearson Correlation test.

## Results

The deviations between the measurements of the 2 instruments are correlated ( $p < 0.001$ ) for both eyes. The strength of the correlation is strong ( $p = 0.707$  for IO and  $p = 0.727$  for AO). The relationship between the measurements of the 2 eyes has a positive direction and therefore one eye follows the upward and downward changes of the other. The relationship is linear (Figure 4) and the distributions of the measurements for both eyes are Poisson (Kolmogorov-Smirnov test). There is a correlation with glaucoma (ANOVA  $p < 0.05$ ), and a trend of correlation with age as the sample increases (Tables 1 and 2). It is speculated that these correlations are due to changes in ocular elasticity both in glaucoma [1] and increasing age [2]. There is no correlation with parameters such as gender, glucose, IOP, refractive abnormalities, thyroid eye disease and cataract ( $p > 0.05$ ) [2,3]. There is no correlation of the measurement discrepancies with the patient's cooperation or not during intraocular pressure measurement with the Diaton (ANOVA,  $p > 0.05$ ). In 31.1% of the sample the deviation of the measurements between the 2 tonometers is zero, in 33.29% the deviation is 1 mmHg, in 18.71% it is 2 mmHg therefore in total in 83.11% of the sample the deviation between the measurements is up to 2 mmHg in absolute value. Diaton has a dynamic range of measurements for values up to 28mmHg (Figure 5). Dynamic measurement range is defined as the range of values between which an instrument is able to measure. It was observed that the Goldmann for IOP values greater than 17 mmHg gives systematically higher measurement values than the Diaton (Figures 6 and 7). Setting the Goldmann leveling tonometer as a reference and the limit as the IOP value of 21 mmHg above which there is hypertonia or suspected glaucoma, and which must be differentially diagnosed, the Diaton gives false positive results in 2.1% of the measured eyes and false negative in 1.75%. A deviation of less than 5mmHg in absolute value between the two eyes measured with the same measuring instrument corresponds to 88.8% of the eyes measured with the Goldmann and 86.6% with the Diaton, while a deviation of more than or equal to 5mmHg, which leads us to suspect glaucoma, corresponds to 11.2%

with the Goldmann and 13.4% with the Diaton. If we take as reference the measurements with Goldmann, Diaton gives 2.2% false positive results for glaucomatous lesions, which raises the suspicion of glaucoma. On the other hand, taking Diaton measurements as a reference, then Goldmann gives 2.2% false negative results for glaucomatous lesions which do not raise the suspicion of glaucoma.

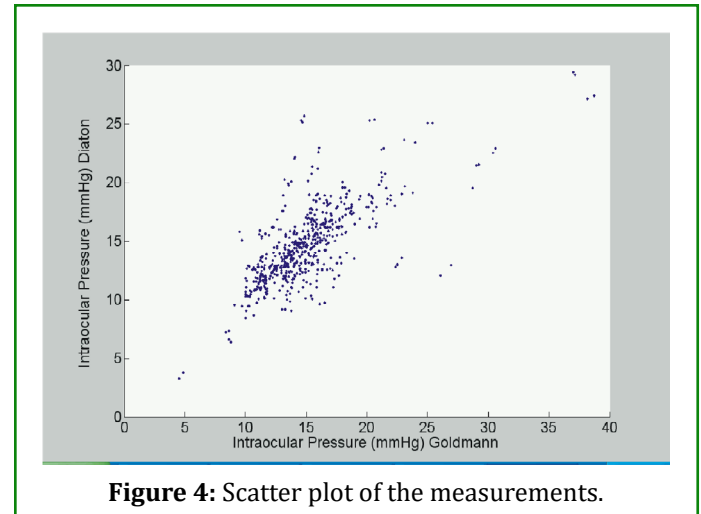


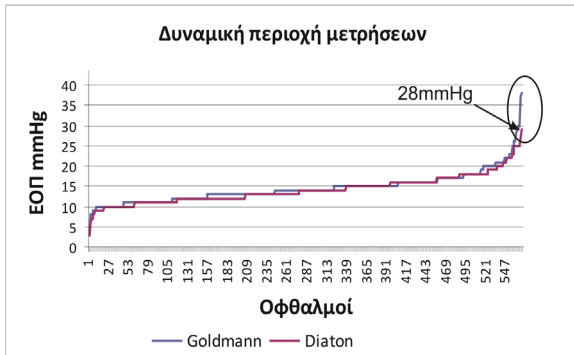
Figure 4: Scatter plot of the measurements.

Age/ Divergence	20- 30	31- 40	41- 50	51- 60	61- 70	71- 80	>80
0	2		4	8	34	36	8
1	2		4	12	34	32	18
2		2	2	4	12	24	
3					2	6	2
4					6	10	2
5			2	2		2	
6						2	
7					2	2	
9						4	
14						2	

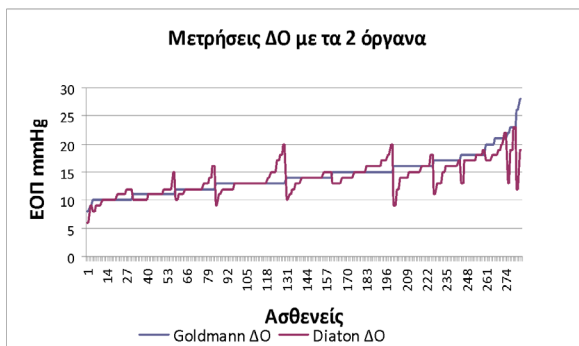
Table 1: Absolute deviation of right eye measurements with respect to age.

Age/ Divergence	20- 30	31- 40	41- 50	51- 60	61- 70	71- 80	>80
0	2		2	2	32	30	8
1	2		2	8	30	30	8
2		2		10	10	28	8
3					6	8	4

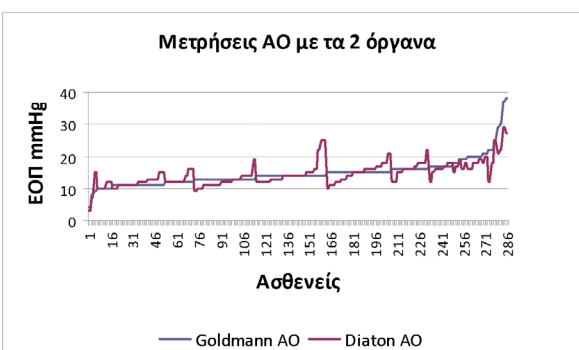
Table 2: Deviation of left eye measurements in absolute value in relation to age.



**Figure 5:** Classified measurements of the EIA with the 2 instruments under study. The classification yields the minimum and maximum measured values that give a measure of the dynamic range of the 2 instruments under study.



**Figure 6:** Classified measurements of right eye EOP based on Goldmann's measurements (blue line). The red line is followed by the corresponding Diaton measurements. The region above 17 mmHg where the Goldmann gives systematically larger measurements is typically visible.



**Figure 7:** Classified measurements of left eye EOP based on Goldmann's measurements (blue line). The red line is followed by the corresponding Diaton measurements. The region above 17 mmHg where the Goldmann gives systematically larger measurements is typically visible.

## Discussion

The Diaton ballistic principle tonometer can be used as an alternative for measuring intraocular pressure over the eyelids in patients with recently operated eyes, after refractive surgery, with corneal trauma, keratitis, corneal epithelial apoptosis, superficial ulcers and large flaps. It can also be used to measure EOP easily in children. Due to the fact that contact with the cornea is avoided, infection with viruses such as HIV, HBV, herpesviruses, adenoviruses included in the tear, as well as any allergic reactions are avoided since the measurement is done without the use of an anaesthetic. It can also be used in cataract patients. The value of intraocular pressure does not depend on the thickness of the cornea. Further research is needed in children with congenital glaucoma and in adults after refractive surgery. Also, for comparisons between the measurements of the 2 instruments, corneal pachymetry should be performed to make the Goldmann measurements more accurate [4,5].

It is considered extremely important that due to the portability of the Diaton tonometer, no ophthalmological equipment is necessary to measure the EOP, which makes it possible to be used by general practitioners for population screening and early diagnosis of glaucoma.

## Conclusion

Correlation of Measurements between Goldmann Applanation Tonometry and Ballistic Principle Diaton Tonometry in Several Groups of Patients

**Purpose:** To compare the intra-ocular pressure [IOP] between the Goldmann with Applanation Tonometry and the Ballistic Principle Diaton Tonometry above the eyelids in different groups of patients. The Diaton tonometer can be used as an alternative for mass measurements of population aiming at the precocious diagnosis of glaucoma.

**Methods:** 572 eyes of 572 patients were studied. The selection of patients is random. The males were the 45.5% of the sample and the females were the 54.5% of the sample being in various ages. The overwhelming majority of the sample is more than 60 years old (Figure 1). The sample is constituted of patients suffering from glaucoma (22.7%), patients suffering from ARMD (24%), diabetics (21.8%) and patients that suffer from none of the above and were named as the group of healthy (43.8%). Obviously, there were a few patients that suffer from glaucoma and simultaneously they were diabetics. The intra-ocular pressure was measured in both eyes from all the above patients with the exception of 2 to whom it was measured only one eye. The IOP was measured with the Goldmann and the Diaton tonometer and the values were recorded. The measurements with the

Goldmann tonometer were carried out by all doctors of the clinic whereas the measurements with the Diaton tonometer were carried out by the same doctor and always with the same method. The patients were at the upright or supine position during the examination with the Diaton tonometer.

There was statistically significant correlation between the measurements of the 2 tonometers ( $p < 0.001$ ). 83.11% of the sample had absolute difference between the values of the two measurements up to 2 mmHg. There is also significant correlation between the "absolute difference between the values of the two measurements" and glaucoma ( $p < 0.05$ ). Moreover, absolute difference between the values of the two measurements seems to be related with age but more measurements are needed to verify this relation statistically. For the so-called "healthy", divergence between the measurements of the 2 tonometers greater than 5mmHg is observed for less than 5% of the sample, whereas for the patients with glaucoma divergence greater than 5mmHg is measured for the 15% of the sample. There is no correlation between divergence and parameters such as gender, diabetes, ARMD, thyroid ophthalmopathy, refractive abnormalities and cataract ( $p > 0.05$ ).

Ballistic Principle Diaton Tonometry can be used as an alternative for the measurement of the intra-ocular pressure above eyelids for patients with recent ocular surgeries, after refractive surgeries, with severe corneal injuries, with corneal apoptosis of epithelium and with large pterygium. Additionally, children can be measured easily with Diaton

for IOP and also it can be used in patients with mobility problems.

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