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Clinical comparison of the American Optical Non-contrast Tonometer and the Digilab Pneumatonometer with the Goldmann Applanation Tanometer

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Abstract

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INTRODUCTION

Concern over intra-ocular pressure (IOP) is not merely of modern day interest. The correlation between high IOP and pathology was recorded by Maimonides in the 12th century.[1]

Consequently, various instruments have been developed to measure this important parameter. From Van Grafe's first indentation model in 1862, Goldmann's applanation model in 1955, and Mackay-Marg's unit in the 1960's to the American Optical Non-contact in 1971, many algorithms have been used to document IOP.[2]

Empirical clinical experience has shown, however, that different instruments yield different IOP readings. It is thus useful to be apprised of how the readings of the various methods compare. This is of extreme importance if one is following pathology secondary to an abnormal IOP.

In this study two methods of tonometry were evaluated, the American Optical Non-contact Tonometer (NCT) and the Digilab Pneumatonometer (PNT). Tonometric results obtained on the same eyes with these two methods were compared to each other and to Goldmann readings taken as a standard. The study sought to answer the following two questions: (1) with respect to the NCT and PNT, how many measures are required to obtain a reading with a reliability equal to that of Goldmann tonometry and (2) how do the IOP's obtained by NCT and PNT compare with those obtained by Goldmann tonometry?

The first question sought to answer the clinical query of how many readings are required to obtain a reliable mean. The operational definition of a reliable mean was the number of readings required to get within plus or minus one mmHg of a mean of 10 readings. One mmHg was chosen because this is the variability reported by Thorburn[3] and Levine [4] for Goldmann. The second question probed issues of comparison of the variability of each method and the trends of the means of the methods.

INSTRUMENTATION

The instruments used in this study were in general use at the Pacific University College of Optometry clinic. They were a Haag-Streit Goldmann Tonometer Model H-03, a Digilab Model 30-R Pneumatonometer and an American Optical Non-contact Tonometer. All instruments were checked for proper functioning before, during, and after the study. Only the three instruments were utilized in this study.

METHODS

Thirty eyes from 24 healthy adult patients were screened for absence of ocular pathology and selected for the study. One drop of Fluress [R] solution was administered to each eye and three Goldmann tonometer readings were taken. A five minute rest was provided while the pneumatonometer was calibrated to zero and the probe cleaned. The pneumatonometer was allowed to warm up for at least twenty minutes before any readings were taken. One drop of ½% proparacaine solution was administered and ten pneumatonometer readings were recorded. The additional anesthetic was required because the benoxinate in the Fluress [R] had a tendency to wear off quickly in some of the subjects. Another five minute rest preceded ten non-contact tonometer measurements. The AO NCT was checked for calibration before tonometry was performed on each subject. The protocol was reversed for half of the subjects with NCT being done first followed by PNT. This is in accordance with standard counterbalancing procedures to control for order effects. Another drop of Fluress [R] was again instilled and a final Goldmann tonometry reading was taken after the final NCT or PNT measurement to ensure that no tonometer-induced drop in IOP had occurred.

Both NCT and PNT are methods which are supposedly self-indicative of the achieving of a correct endpoint; the NCT display doesn't blink and the PNT "beeps" when the designer's criteria for a "correct" measurement have been fulfilled.

The endpoint of Goldmann, however well defined, is more subjective. Therefore, to ensure the validity and repeatability of our Goldmann readings, a double-blind pilot study was done. The difference between the researcher's Goldmann readings and the clinical advisor's readings was never more than 1mmHg (and was seldom that much).

RESULTS AND DISCUSSION

PART I

Initially, whether repeated measures of NCT or PNT to an eye would cause a decrease in IOP due to a massage effect would first have to be ruled out to ensure the face validity of this part of the study. The literature suggests there is no massage effect.[5,6,7] The comparison of our first Goldmann reading with the last one taken after the 10 NCT and 10 PNT readings show the following: (data in Appendix I)

final Goldmann reading 2mmHg higher than first	1/30
final Goldmann reading 1mmHg higher than first	5/30
no difference	11/30
final Goldmann reading 1mmHg lower than first	7/30
final Goldmann reading 2mmHg lower than first	5/30
final Goldmann reading 4mmHg lower than first	1/30

Since the massage effect would cause a lowering, the values higher than the initial are probably due to the variability of Goldmann tonometry. Six out of 30 cases are lower and 1 out of 30 cases higher than the accepted 2mmHg range of Goldmann tonometry. We do not feel that these data show any trend of a massage effect.

For each eye, a tally was run to see how many measures were required to obtain a mean within one mmHg of the mean of the ten measures for that eye on that instrument. The results follow.

NCT

Number of eyes in which the first measure was of this tolerance: 23 out of 30 (77%)

Number of eyes in which a mean of the first two measures was required to give a mean of this tolerance: 6 out of 30 (20%)

Number of eyes in which a mean of the first three measures was require to give a mean of this tolerance: 1 out of 30 (3%)

Thus, with respect to NCT, a mean of the first 3 measures gave a mean within 1mmHg of the mean of the ten measures in 100% of the eyes tested. This is in agreement with the works of Myers,[8] Myers and Scott,[6] and Grolman.[1]

PNT

Number of eyes in which the first measure was of this tolerance: 30 out of 30 (100%)

Thus, with respect to PNT, the first measure was within 1mmHg of the mean of the ten measures in 100% of the eyes tested.

PART II

For internal validity of this part of the study, the Goldmann readings taken by the researchers had to have such low variability that Goldmann readings could be taken as a standard. That is, that three Goldmann readings taken on each eye of the subject differed by no more than 1mmHg from each other (i.e. a range of 2mmHg). It can be seen by examination that the data (Appendix I) for all 30 subjects meets this criteria.

To compare Goldmann to NCT and Goldmann to PNT, a two-tailed Studentized t-test for dependant samples[9] was used. For each subject the value chosen to be used in the t-test was determined as follows:

Goldmann: the initial reading taken.

NCT: the mean of the first three readings.

PNT: the initial reading taken.

The choices for NCT and PNT were made based on the results of Part I of this study. The t-test was conducted according to standard statistical procedures. The results of the t-test are as follows: (Appendix II)

Goldmann vs. NCT $t_{calculated} = 11.4$

Goldmann vs. PNT $t_{calculated} = 0.99$

Degrees of freedom are calculated by subtracting 1 from the number of subjects. The t-table values for this many degrees of freedom is 3.396 at the .001 level.[10] Thus, the null hypothesis can be rejected only in the case of NCT. That is, the probability that the different readings obtained on an eye by Goldmann and NCT are merely by chance and not due to differences in the methods are 1 in 1000. However, the difference in readings between Goldmann and PNT was not shown to be significant at this level or even the 0.1 level.

A Repeated-Measure ANOVA was also run on this data. In the following table the sum-of-squares (SS) sources of variance and the degree of freedom (df), and mean squares (ms) for subjects, treatments, and errors are presented. The *F* statistic is shown to be 239.16 and is significant at the .001 level.

Source	SS	df	ms	F
Total	2446	269	--	
Subjects	1516	29	--	239.16
Treatments	621	2	310.5	p .001
Error	309	238	1.30	

That the *F* statistic is significant indicates that "there are significant differences somewhere within the data."[11] That is, the probability is less than 1 chance in 1000 that the data turned out the way it did merely due to chance. The location of the differences--does NCT yield different results than Goldmann, and/or does PNT yield different results than Goldmann-- can be elicited only by *post-hoc* tests.[12] The *post-hoc* test chosen here was the Tukey HSD test.[12] However, the Tukey HSD test was inconclusive.

CONCLUSION

In agreement with previous studies, a mean of 3 NCT readings would give a result within 1mmHg of multiple NCT readings in a given eye in 100% of the cases.[1,6,8] To yield a reading within this criterion range using the PNT, only the first reading would be required.

NCT was found to be significantly different than Goldmann at the .001 level. Although a trend analysis was not applied to these data, NCT was lower than Goldmann in 100% of the cases examined. In short, clinically speaking, the probability is high that a NCT reading will be lower than a Goldmann reading on the same eye. This rank order is not in agreement with other literature.[2,6,13,14,15,16,17,18] As noted in the Methods Section, this anomaly could not be attributed to differences in Goldmann methodology.

PNT was not found to differ significantly from Goldmann. The null hypothesis could not be rejected. Clinically speaking, the probability is high that a PNT measure will be approximately the same as a Goldmann measure. Since the methods are not shown to be significantly different, no statement about a high/low trend of PNT with respect to Goldmann can legitimately be made.

Appendix I.

subject.	1st GLD.			Final Gld
1	15, 15, 14	NC	10 11 9 9 11 11 10 12 11 10	15
		PN	16 16 16 15 16 16 16 16 16 15	
2	16, 16. 15	NC	11 12 11 9 10 10 9 8 9 10	12
		PN	11 11 11 12 11 12 12 12 12 12	
3	14, 14, 14	NC	12 9 9 11 10 10 9 9 11 9	12
		PN	12 13 13 13 13 13 14 13 14 14	
4	12 14 12.	NC	10 10 10 10 9 9 10 9 11 9	12
		PN	12 12 13 12 13 14 13 13 12 13	
5	16 16 16	NC	11 10 11 11 11 9 11 10 13 10	15
		PN	14 14 13 14 13 13 13 13 13 14	
6	17 17 17	NC	11 13 14 11 11 13 10 10 10 11	15
		PN	14 14 14 13 14 14 13 13 13 12	
7	9 10 9	NC	6 6 6 6 6 6 7 6 7 7	9
		PN	10 10 10 10 9 10 10 9 10 10	
8	9 10 10	NC	7 7 6 5 8 6 7 7 6 5	10
		PN	12 12 12 11 11 12 11 11 11 11	
9	10 10 10	NC	10 9 8 9 10 9 9 9 10 9	12
		PN	13 13 12 12 12 13 13 13 12 13	
10	10 10 10	NC	9 12 10 10 9 11 9 10 11 11	10
		PN	12 12 12 13 12 12 13 12 12 12	
11	11 10 11	NC	7 9 6 6 6 6 7 6 7 6	10
		PN	12 12 11 12 12 12 11 11 11 11	

Appendix I

sub	1st GLD			Final Gld.
12	11 11 11	NC	9 10 9 9 8 8 7 8 7 7	10
		PN	11 11 11 10 11 11 10 11 11 11	
13	10 10 10	NC	8 8 7 8 8 5 7 6 5 5	10
		PN	10 10 10 10 11 11 11 11 10 11	
14	10 11 10	NC	8 8 7 8 7 7 8 10 6 7	10
		PN	11 11 10 11 10 10 11 11 10 10	
15	18 20 18	NC	16 17 16 15 15 15 16 16 15 15	18
		PN	15 15 15 14 14 15 15 15 16 15	
16	15 15 15	NC	13 13 10 11 11 10 11 10 10 11	14
		PN	15 15 14 13 14 13 14 13 13 14	
17	20 20 [illegible]	NC	20 19 17 16 17 17 16 19 20 17	21
		PN	19 20 20 17 18 18 18 17 18 17	
18	12 12 12	NC	9 8 8 11 9 9 9 10 11 7	12
		PN	12 13 13 13 13 13 12 13 13 13	
19	14 12 12	NC	[illegible] 7 8 10 9 7 8 9 10 8	11
		PN	12 13 12 13 12 13 13 12 12 13	
20	12 11 12	NC	8 8 9 7 9 8 7 8 7 8	10
		PN	9 10 10 10 10 11 10 10 [illegible] 9	
21	12 12 12	NC	9 9 9 11 10 10 11 10 11 9	13
		PN	14 13 13 13 13 12 13 14 [illegible] 13	
22	16 15 15	NC	13 11 10 12 13 12 11 11 11 10	15
		PN	15 15 14 15 14 15 16 15 16 15	

Appendix I

subj.	1st Gld.			Final Gld.
23	11 10 12	NC	5 4 4 4 5 4 5 4 4 5	9
		PN	10 9 10 10 10 10 9 10 10 10	
24	13 14 14	NC	11 11 9 12 10 11 12 9 13 11	14
		PN	13 14 13 13 13 13 14 12 12 13	
25	12 14 13	NC	10 10 9 11 10 11 11 11 10 10	13
		PN	13 13 13 13 13 12 12 13 12 13	
26	16 16 16	NC	8 10 10 9 10 10 9 9 9 9	15
		PN	15 15 15 14 15 15 16 16 15 15	
27	14 15 15	NC	10 8 9 8 7 7 8 8 7 8	12
		PN	14 13 14 15 13 14 14 14 13 15	
28	12 13 13	NC	11 9 9 9 10 10 8 11 9 9	11
		PN	12 12 13 13 14 14 13 12 13 14	
29	14 14 14	NC	11 9 11 10 10 10 9 12 11 10	14
		PN	13 13 13 14 13 14 14 13 13 14	
30	10 11 11	NC	10 8 8 7 8 8 8 7 8 7	10
		PN	10 9 9 10 9 10 10 9 10 10	

Appendix II

sub	GLD	NCT	PNT	(Gld-NCT)	$(Gld-NCT)^2$	(Gld-PNT)	$(Gld-PNT)^2$
1	11	7	12	4	16	-1	1
2	11	9	11	3	9	0	0
3	10	8	10	2	4	0	0
4	10	8	11	2	4	-1	1
5	18	16	15	2	4	3	9
6	15	12	15	3	9	0	0
7	20	19	19	1	1	1	1
8	12	8	12	4	16	0	0
9	14	8	12	6	36	2	4
10	12	8	9	4	4	3	9
11	12	9	14	3	3	-2	4
12	16	11	15	5	25	1	1
13	15	10	16	5	25	-1	1
14	16	11	11	5	25	5	25
15	14	10	12	4	16	2	4
16	12	10	12	2	4	0	0
17	14	11	14	5	25	2	4
18	17	13	14	4	16	3	9
19	9	6	10	3	9	-1	1
20	9	7	12	2	4	-3	9
21	10	9	13	1	1	-3	9
22	10	10	12	0	0	-2	4
23	11	4	10	7	49	1	1
24	13	10	13	3	9	0	0
25	12	10	13	2	4	-1	1
26	16	9	15	7	49	1	1
27	14	9	14	5	25	0	0
28	12	9	12	2	4	0	0
29	14	10	13	4	16	1	1
30	10	10	10	2	4	0	0
				102	424	10	100

Appendix II

For NCT.

$$\bar{X}_D = \frac{\Sigma D}{N} = \frac{102}{30} = 3.4$$

$$t = \frac{X_D\sqrt{N-1}}{SD_D}$$

$$SD_D = \sqrt{\frac{\Sigma D^2}{N} - \bar{X}_D^2}$$

$$t = \frac{3.4\sqrt{29}}{1.6}$$

$$= \sqrt{\frac{424}{30} - (3.4)^2}$$

$$t = 11.4138$$

$$= 1.6$$

For PNT

$$t = \frac{\bar{X}_D\sqrt{N-1}}{SD_D}$$

$$\bar{X}_D = \frac{\Sigma D}{N} = \frac{10}{30} = .33$$

$$SD_D = \sqrt{\frac{\Sigma D^2}{N} - \bar{X}_D^2}$$

$$t = \frac{.33\sqrt{29}}{1.8}$$

$$= \sqrt{\frac{100}{30} - (.33)^2}$$

$$t = .9997$$

$$= 1.8$$

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