5-1970

Determination of the reliability of the Gamb's ophthalmometer

Andrew Y. Maeda
Pacific University

Leif W. Johnson
Pacific University

Determination of the reliability of the Gamb's ophthalmometer

Abstract

The purpose of this study is to report our findings and impressions concerning the reliability of corneal radius readings possible with the Gamb's Ophthalmometer.

Degree Type

Thesis

Degree Name

Master of Science in Vision Science

Committee Chair

Niles Roth

Subject Categories

Optometry

DETERMINATION OF THE RELIABILITY OF THE GAMB'S OPHTHALMOMETER

by

Andrew Y. Maeda

Leif W. Johnson

Submitted in partial fulfillment
of the requirements for the College of Optometry
at Pacific University

May, 1970

Approved by: Niles Roth
Niles Roth O.D., Ph.D.

ACKNOWLEDGMENTS

Our sincere gratitude is extended to Dr. Niles Roth, Associate Professor of Physiological Optics and Optometry, whose guidance and inspiration during this study played a major role in it's successful completion. Our thanks also to the people who took time from their work to serve as subjects for this study.

PURPOSE OF THIS STUDY

The purpose of this study is to report our findings and impressions concerning the reliability of corneal radius readings possible with the Gamb's Ophthalmometer.

TABLE OF CONTENTS

INTRODUCTION

In general, most practitioners have more confidence in the accuracy of corneal radius readings obtained by more commonly used instruments than is warranted. According to several studies done on the reliability of other commonly used instruments for determining corneal radius, these instruments have shown more variability than most practitioners would be willing to admit.

After a casual encounter with the Gamb's Ophthalmometer, we were impressed with the clarity and distinctness of the mires, ease of operation and precise movements of all parts. With the criteria we used, it seemed a more superior instrument for taking corneal curvatures than any others we had previously employed. The ultimate question was: "Could it do what it was designed to do -- could it take accurate and reliable corneal curvature readings?"

In summary, some of the features the manufacturer points out in the manual are: The optical system of the Gamb's Ophthalmometer is based on the Helmholtz principle, which is the doubling that affects the measurement occurring along two axes parallel to the principal optical axis. Therefore, this doubling remains independent of the variations of the focal distance, in contrast with

the angular doubling apparatus of the Javal or related types. The measurement is entirely free of the common causes of error: (1)the operator's accommodation between two measurements; (2)the operator's uncorrected astigmatism; (3) difficulty or omission of adjusting the distance to the eye before each measurement.

The optical system of the Gamb's Ophthalmometer offers a large number of advantages: (1)exact and constant measurements; (2)high luminosity, enabling precise observation of fixation and centering; (3)patient can see the luminous internal axial fixation point to infinity; (4) smooth operation of instrument; (5)readings grouped in a single well-lit eyepiece designed to eliminate all parallax; and (6)two sets of mires incorporated into the instrument. The change of mires is made by rotating a small lever in front of the revolving apparatus. One set of mires is the stair step type for approximate radius measurement. One of the mires is red and the other is green. The other set is monochromatic concentric crosses, yielding precise measurements of corneal curvature.

The corneal curvatures are given in both dioptric values and millimeters of radius. The Gamb's Ophthalmometer is calibrated for a refractive index of 1.337, which corresponds to the average index of the cornea-aqueous humor.

PROCEDURE

To determine the reliability of the Gamb's Ophthalmometer, seven human eyes in four subjects, four spherical standards and one toric standard were used. Each examiner took five readings on each surface in each principal meridian. One examiner served as a subject, thus he measured five rather than seven human corneas. The spherical standards were measured at 180 degrees and 90 degrees. In this manner, 1,100 radius findings were obtained in the study.

The measurements were taken at the same time each day to avoid any diurnal variations which might affect the radii of the human corneas. The measurements were taken on Monday and Wednesday for two and a half weeks or until five sessions had been completed on each surface.

After each reading, the instrument was thrown out of focus and then refocused for the other principal meridian.

As was previously stated in the introduction, the instrument has two sets of mires. We chose to use the monochromatic concentric crosses. The manufacturer states that these mires were designed for precise measurements. Figure 1 illustrates how the concentric cross appears to the examiner.

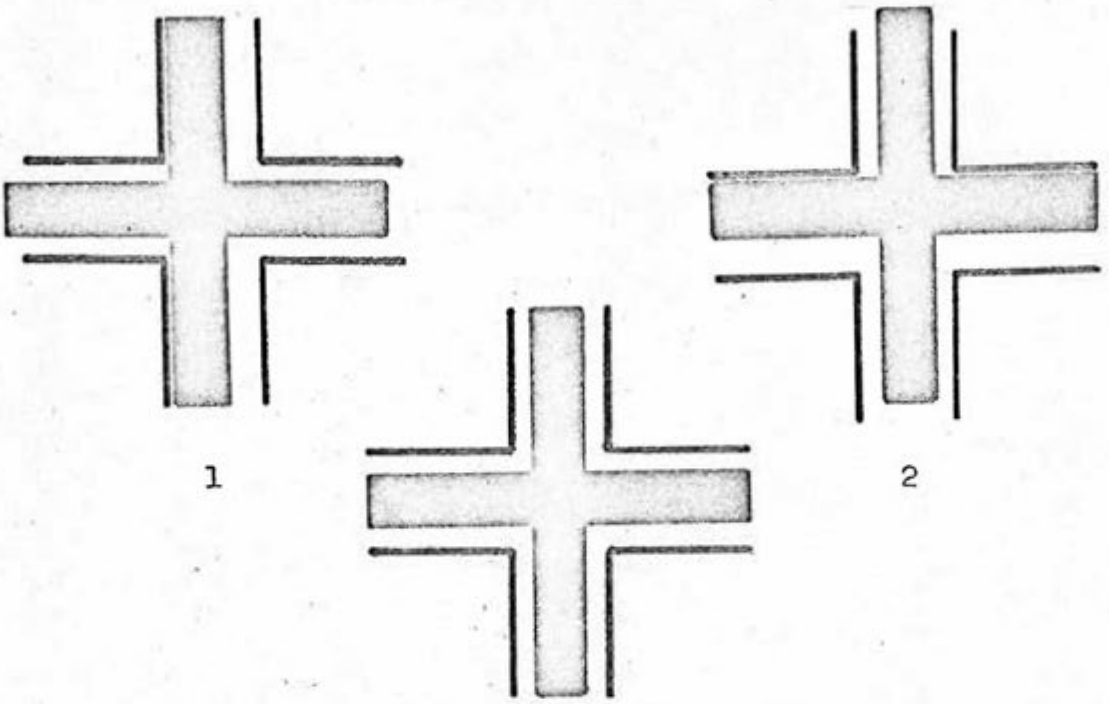


Figure 1

(1) Mires in focus but in need of additional radius adjustment.

(2) Mires in focus but in need of additional meridional adjustment.

(3) Mires in focus and proper radius and meridional adjustment.

We chose to record the radius findings in millimeters rather than diopter values. Conversion factors will be provided later in the paper to allow conversion of the data to the more familiar dioptric values.

An inherent calibration error was present in the instrument which prevented the examiners from finding exact principal meridan locations, unless 0.75D minimum toricity was present on the measuring surfaces. This fact,

however, was irrelevant because the question at hand was the reliability of the findings, not their validity.

RAW DATA SHEET

Examiner #1

Human Cornea #1

180		90	
7.850	@176.0	8.212	@98.0
7.875	@175.8	8.225	@95.7
7.862	@175.7	8.212	@97.2
7.875	@175.0	8.225	@97.0
7.875	@173.7	8.225	@97.0
7.837	@177.2	8.200	@92.8
7.837	@173.7	8.175	@94.4
7.850	@172.2	8.200	@91.2
7.862	@171.8	8.200	@91.8
7.850	@173.5	8.187	@93.6
7.875	@175.5	8.225	@93.3
7.862	@179.2	8.175	@93.4
7.875	@176.0	8.225	@94.2
7.875	@176.8	8.200	@95.0
7.875	@174.2	8.237	@96.8
7.850	@173.8	8.200	@90.8
7.862	@170.8	8.200	@92.8
7.850	@173.2	8.200	@91.2
7.862	@175.7	8.200	@91.2
7.850	@175.5	8.212	@91.0
7.862	@173.6	8.225	@93.5
7.850	@172.8	8.212	@92.0
7.831	@172.5	8.225	@92.9
7.850	@172.9	8.225	@91.7
7.862	@174.0	8.237	@94.6

Examiner #1

Human Cornea #2

7.775	@13.7	7.100	@94.5
7.775	@14.1	7.100	@95.0
7.775	@13.0	7.100	@95.5
7.775	@13.5	7.100	@95.2
7.775	@13.2	7.100	@95.0
7.787	@ 9.8	7.125	@91.3
7.775	@ 9.3	7.100	@92.2
7.775	@ 9.6	7.100	@92.5
7.787	@ 9.6	7.100	@90.7
7.750	@ 9.8	7.100	@91.5
7.775	@ 9.0	7.100	@94.8
7.787	@ 9.1	7.100	@95.1
7.775	@ 8.4	7.100	@94.2
7.762	@ 9.0	7.100	@94.2
7.775	@ 8.9	7.112	@95.0
7.775	@ 7.5	7.087	@92.3
7.750	@ 8.3	7.100	@94.5
7.750	@ 8.3	7.125	@94.0
7.750	@ 7.5	7.100	@93.5
7.775	@ 8.4	7.125	@94.2
7.762	@ 9.0	7.100	@94.5
7.775	@ 8.3	7.125	@93.6
7.750	@ 7.5	7.112	@92.9
7.762	@ 8.4	7.125	@94.0
7.750	@ 8.9	7.100	@95.1

RAW DATA SHEET

Examiner #1

Human Cornea #3

7.737	@2	6.962	@83.0
7.725	@1.1	6.962	@83.5
7.725	@1.0	6.950	@82.8
7.725	@1.1	6.962	@83.1
7.737	@1.2	6.950	@82.9
7.725	@178.5	6.975	@79.3
7.737	@178.6	6.962	@80.3
7.737	@177.6	6.950	@80.0
7.737	@178.5	6.962	@80.2
7.750	@178.0	6.950	@80.0
7.712	@178.0	6.937	@83.3
7.725	@178.0	6.950	@83.5
7.737	@178.0	6.950	@83.6
7.725	@178.4	6.937	@82.0
7.750	@176.4	6.950	@82.3
7.712	@176.0	6.950	@83.5
7.712	@176.5	6.975	@83.5
7.712	@177.0	6.975	@84.1
7.700	@179.2	6.950	@83.8
7.725	@177.0	6.975	@84.1
7.712	@176.1	6.950	@83.5
7.700	@177.0	6.975	@80.1
7.700	@176.1	6.950	@84.1
7.725	@175.2	6.975	@83.5
7.737	@177.0	6.962	@84.8

RAW DATA SHEET

Examiner #1

Human Cornea #4

7.650	@177.4	7.000	@82.0
7.637	@175.5	7.025	@77.2
7.625	@176.0	7.000	@77.4
7.625	@176.0	7.000	@79.5
7.637	@175.6	7.025	@80.0
7.625	@175.8	7.025	@77.2
7.625	@176.2	7.012	@78.5
7.625	@175.5	7.012	@78.9
7.625	@177.0	7.000	@78.4
7.625	@174.8	7.012	@77.4
7.612	@174.3	6.987	@74.7
7.612	@175.0	6.987	@77.6
7.612	@175.5	6.987	@77.5
7.625	@174.3	7.012	@77.5
7.625	@174.0	7.000	@76.3
7.625	@172.8	7.000	@78.1
7.600	@174.8	7.000	@79.0
7.612	@173.5	7.012	@76.8
7.612	@174.6	7.012	@78.4
7.612	@174.6	7.000	@78.6
7.625	@176.5	7.000	@78.4
7.637	@176.1	6.987	@77.9
7.625	@176.4	7.012	@78.8
7.637	@176.8	7.025	@80.1
7.637	@175.8	7.012	@77.6

RAW DATA SHEET

Examiner #1

Human Cornea #5

7.667	@4.0	6.962	@88.0
7.650	@3.9	6.962	@87.5
7.675	@4.6	6.975	@87.2
7.675	@3.5	6.987	@86.5
7.662	@3.5	6.975	@85.5
7.650	@4.5	6.975	@86.9
7.662	@2.8	6.975	@86.9
7.662	@4.3	6.975	@85.8
7.662	@3.0	6.962	@85.1
7.650	@2.9	6.975	@87.0
7.650	@5.8	6.950	@88.7
7.650	@6.2	6.962	@89.1
7.650	@5.0	6.987	@89.0
7.650	@6.1	6.962	@87.7
7.650	@6.4	6.975	@87.0
7.650	@5.1	6.987	@90.0
7.637	@5.2	6.975	@88.8
7.650	@4.2	6.987	@88.5
7.650	@3.8	6.962	@88.8
7.662	@3.0	6.975	@87.6
7.650	@5.8	6.975	@85.9
7.650	@6.3	6.975	@86.3
7.675	@4.8	6.962	@89.6
7.650	@5.0	6.975	@87.6
7.650	@4.3	6.962	@87.3

Examiner #1

Human Cornea #6

8.812	@1.8	7.425	@88.0
8.200	@1.9	7.450	@87.0
8.225	@3.5	7.450	@86.8
8.237	@2.6	7.437	@85.5
8.225	@3.2	7.450	@86.0
8.225	@1.5	7.437	@82.2
8.250	@1.2	7.425	@83.0
8.237	@2.0	7.437	@84.0
8.225	@0	7.450	@85.0
8.225	@1.0	7.425	@87.1
8.225	@3.1	7.450	@84.3
8.237	@2.0	7.450	@86.5
8.225	@2.3	7.450	@84.0
8.212	@2.2	7.450	@83.2
8.225	@2.5	7.450	@85.3
8.237	@4.0	7.487	@83.2
8,250	@1.8	7.475	@84.0
8.262	@2.7	7.462	@82.8
8.237	@3.0	7.462	@82.2
8.250	@2.0	7.487	@81.0
8.200	@0.5	7.425	@86.2
8.200	@1.5	7.425	@86.2
8.225	@0.4	7.425	@84.8
8.225	@1.8	7.437	@84.8
8.225	@1.0	7.412	@83.9
8.225	@3.6	7.487	@87.4
8.200	@4.0	7.475	@88.0
8.212	@3.8	7.487	@86.1
8.225	@2.0	7.487	@85.0
8.225	@2.0	7.475	@85.0

RAW DATA SHEET

Examiner #1

Human Cornea #7

8.212	@178.1	7.212	@83.5
8.200	@178.5	7.212	@83.1
8.225	@177.3	7.200	@82.1
8.212	@178.0	7.200	@82.0
8.200	@177.0	7.175	@81.8
8.212	@177.3	7.225	@79.0
8.212	@177.1	7.187	@79.5
8.237	@175.0	7.225	@79.8
8.225	@176.5	7.200	@79.8
8.212	@177.1	7.187	@79.8
8.225	@177.3	7.212	@83.0
8.200	@178.9	7.200	@82.0
8.200	@177.2	7.212	@79.8
8.212	@177.2	7.212	@81.0
8.200	@176.8	7.200	@81.3
8.200	@178.0	7.212	@81.7
8.200	@177.2	7.225	@80.8
8.200	@177.5	7.200	@81.5
8.225	@178.0	7.212	@81.5
8.200	@178.6	7.200	@81.5
8.200	@178.5	7.250	@85.0
8.187	@177.7	7.237	@84.2
8.187	@178.0	7.237	@85.1
8.200	@177.0	7.237	@83.2
8.187	@176.1	7.225	@81.0
8.200	@176.2	7.262	@82.0
8.200	@176.0	7.237	@83.4
8.200	@177.8	7.225	@83.0
8.187	@177.0	7.250	@84.2
8.187	@177.8	7.262	@83.4

STEEL BALL # 1		STEEL BALL # 2	
180	90	180	90
8.312	8.300	7.537	7.525
8.312	8.300	7.537	7.512
8.300	8.312	7.525	7.525
8.312	8.312	7.537	7.525
8.312	8.312	7.525	7.512
8.300	8.300	7.525	7.512
8.300	8.300	7.525	7.500
8.312	8.312	7.525	7.512
8.312	8.300	7.512	7.512
8.312	8.312	7.525	7.525
8.312	8.312	7.525	7.512
8.312	8.312	7.525	7.512
8.325	8.312	7.512	7.525
8.300	8.300	7.525	7.525
8.300	8.300	7.537	7.525
8.312	8.312	7.525	7.512
8.312	8.312	7.525	7.525
8.300	8.300	7.537	7.525
8.312	8.312	7.525	7.512
8.312	8.312	7.525	7.525
8.300	8.325	7.525	7.525
8.312	8.312	7.525	7.512
8.325	8.312	7.512	7.525
8.312	8.325	7.512	7.512
8.325	8.312	7.512	7.512

STEEL BALL # 3

180	90
8.712	8.725
8.725	8.700
8.712	8.700
8.725	8.687
8.700	8.700
8.712	8.725
8.712	8.725
8.725	8.712
8.712	8.725
8.725	8.737
8.700	8.725
8.712	8.725
8.712	8.712
8.712	8.700
8.725	8.712
8.712	8.700
8.725	8.712
8.712	8.712
8.725	8.725
8.712	8.725
8.712	8.712
8.712	8.725
8.725	8.725
8.712	8.725

STEEL BALL # 4

180	90
7.125	7.150
7.125	7.125
7.137	7.137
7.125	7.137
7.125	7.125
7.125	7.125
7.125	7.125
7.125	7.125
7.125	7.137
7.137	7.125
7.125	7.137
7.125	7.137
7.125	7.125
7.112	7.125
7.125	7.125
7.125	7.125
7.137	7.137
7.125	7.137
7.125	7.125
7.125	7.112
7.112	7.112
7.137	7.125
7.125	7.125

7.600	@140.2	7.700	@87.8
7.600	@141.1	7.700	@87.1
7.600	@144.5	7.687	@88.0
7.600	@143.0	7.687	@90.5
7.600	@144.6	7.700	@90.9
7.575	@146.7	7.700	@83.6
7.575	@144.3	7.725	@83.0
7.575	@143.2	7.725	@82.3
7.575	@147.0	7.712	@84.5
7.575	@146.3	7.712	@86.2
7.550	@145.4	7.700	@91.0
7.562	@147.3	7.700	@90.8
7.562	@148.3	7.687	@91.7
7.562	@146.2	7.700	@90.5
7.575	@145.5	7.700	@91.1
7.575	@146.0	7.700	@92.4
7.575	@144.0	7.712	@87.0
7.575	@144.5	7.700	@89.0
7.575	@142.3	7.700	@90.5
7.575	@145.5	7.700	@88.3
7.562	@146.1	7.725	@89.1
7.575	@148.3	7.700	@91.9
7.575	@143.0	7.712	@86.0
7.575	@144.0	7.700	@93.2
7.587	@144.6	7.712	@94.5

RAW DATA SHEET

Examiner #2

Human Cornea #1

7.875	@172.3	8.225	@96.4
7.875	@173.0	8.200	@96.6
7.900	@172.9	8.225	@96.3
7.900	@171.0	8.175	@96.0
7.900	@172.0	8.237	@96.0
7.875	@173.0	8.187	@92.0
7.862	@173.2	8.200	@93.2
7.875	@171.0	8.175	@93.0
7.850	@172.0	8.200	@92.6
7.850	@171.0	8.175	@93.7
7.887	@174.0	8.225	@95.0
7.900	@174.0	8.200	@97.6
7.900	@172.0	8.225	@98.1
7.900	@171.2	8.200	@96.8
7.900	@171.1	8.200	@95.1
7.900	@173.4	8.212	@91.3
7.900	@174.0	8.212	@93.2
7.850	@172.0	8.212	@90.0
7.875	@172.6	8.225	@91.8
7.850	@173.9	8.200	@90.9
7.875	@172.8	8.212	@92.1
7.850	@173.6	8.200	@91.6
7.887	@173.9	8.225	@92.5
7.975	@173.0	8.225	@93.0
7.875	@174.0	8.212	@94.0

RAW DATA SHEET

Examiner #2

Human Cornea #2

7.775	@14.2	7.100	@94.0
7.800	@13.2	7.100	@92.3
7.800	@14.7	7.100	@93.0
7.750	@14.3	7.100	@94.0
7.762	@13.1	7.100	@93.0
7.775	@14.0	7.100	@91.0
7.800	@13.9	7.112	@94.0
7.775	@13.8	7.100	@94.5
7.762	@14.7	7.100	@93.2
7.775	@14.6	7.100	@95.0
7.800	@ 8.4	7.087	@95.2
7.775	@10.6	7.075	@94.2
7.775	@10.5	7.087	@95.1
7.775	@10.1	7.100	@94.9
7.800	@10.0	7.075	@94.3
7.775	@14.0	7.100	@96.6
7.762	@11.0	7.100	@95.0
7.775	@12.3	7.100	@96.0
7.775	@12.0	7.087	@96.2
7.775	@11.6	7.100	@95.0
7.750	@12.0	7.100	@94.6
7.762	@11.5	7.087	@95.4
7.762	@12.6	7.712	@93.1
7.775	@10.6	7.750	@92.8
7.775	@ 9.6	7.750	@94.0

RAW DATA SHEET

Examiner #2

Human Cornea #3

7.725	@ 3.9	6.925	@84.5
7.725	@ 3.5	6.925	@83.2
7.725	@ 4.0	6.925	@83.8
7.725	@ 3.8	6.925	@83.8
7.725	@ 3.9	6.925	@84.1
7.750	@179.0	6.962	@80.2
7.750	@179.3	6.950	@81.2
7.750	@179.1	6.950	@79.7
7.750	@178.1	6.937	@79.5
7.750	@179.0	6.937	@80.1
7.725	@179.8	6.925	@83.7
7.725	@179.8	6.925	@82.7
7.737	@179.4	6.925	@83.0
7.737	@178.9	6.925	@84.0
7.737	@179.3	6.925	@83.4
7.700	@179.5	6.962	@83.2
7.737	@179.5	6.950	@81.6
7.750	@179.0	6.925	@82.0
7.725	@177.3	6.975	@81.0
7.700	@179.5	6.962	@80.8
7.750	@178.4	6.950	@80.0
7.737	@177.4	6.962	@81.4
7.725	@ 1.0	6.925	@83.6
7.737	@ 0.0	6.937	@85.1
7.750	@179.2	6.925	@84.6

RAW DATA SHEET

Examiner #2

Human Cornea #4

7.650	@178.0	7.000	@79.0
7.625	@179.5	7.000	@79.2
7.612	@179.0	7.012	@77.0
7.625	@179.2	7.000	@77.8
7.625	@179.5	7.037	@76.0
7.637	@176.3	6.987	@77.0
7.637	@178.0	7.000	@75.8
7.637	@178.1	6.987	@75.8
7.637	@176.0	7.000	@78.5
7.650	@176.0	7.000	@75.8
7.600	@175.0	7.000	@80.0
7.625	@175.9	7.000	@75.0
7.600	@175.0	7.000	@76.2
7.587	@176.4	7.012	@73.8
7.612	@176.6	7.000	@74.5
7.625	@174.5	7.025	@75.4
7.600	@175.0	7.025	@73.4
7.600	@174.2	7.037	@73.0
7.625	@177.0	7.037	@74.1
7.612	@175.1	7.025	@73.5
7.625	@176.5	7.012	@73.6
7.612	@175.6	7.000	@79.0
7.625	@175.6	7.012	@73.5
7.625	@178.5	7.025	@74.7
7.650	@175.6	7.012	@76.4

RAW DATA SHEET

Examiner #2

Human Cornea #5

7.650	@10.0	6.887	@89.0
7.650	@ 7.0	7.000	@88.7
7.625	@ 9.0	7.000	@89.0
7.625	@ 9.0	7.000	@86.0
7.650	@ 5.5	7.000	@86.0
7.650	@ 4.8	6.962	@87.0
7.650	@ 4.8	6.975	@85.8
7.650	@ 4.6	6.975	@85.8
7.650	@ 4.4	6.962	@85.5
7.662	@ 5.1	6.975	@85.0
7.687	@ 5.7	6.975	@85.5
7.650	@ 5.5	6.975	@84.5
7.650	@ 5.2	6.975	@84.4
7.650	@ 5.0	6.975	@85.0
7.650	@ 5.0	6.975	@86.7
7.662	@ 4.8	6.975	@87.9
7.650	@ 5.2	6.975	@87.0
7.650	@ 4.8	6.975	@88.2
7.637	@ 3.9	6.950	@87.1
7.650	@ 4.5	6.962	@86.7
7.637	@ 4.0	6.975	@84.6
7.650	@ 5.1	6.962	@86.5
7.637	@ 4.4	6.975	@85.9
7.650	@ 5.5	6.975	@85.6
7.650	@ 5.3	6.962	@85.9

STEEL BALL # 1

180	90
8.325	8.312
8.325	8.312
8.325	8.325
8.312	8.312
8.325	8.325
8.312	8.325
8.312	8.312
8.312	8.325
8.325	8.325
8.325	8.325
8.325	8.312
8.312	8.312
8.312	8.325
8.325	8.325
8.325	8.325
8.325	8.312
8.312	8.312
8.325	8.325
8.325	8.312
8.325	8.325
8.325	8.325
8.325	8.325
8.325	8.312
8.325	8.325
8.312	8.325

STEEL BALL # 2

180	90
7.525	7.550
7.525	7.562
7.500	7.562
7.500	7.575
7.525	7.575
7.525	7.550
7.537	7.537
7.525	7.537
7.525	7.525
7.525	7.550
7.537	7.537
7.525	7.537
7.537	7.550
7.525	7.525
7.525	7.550
7.525	7.537
7.525	7.525
7.537	7.537
7.512	7.550
7.525	7.525
7.525	7.525
7.525	7.525
7.512	7.525
7.512	7.512
7.525	7.525

STEEL BALL # 3

180	90
8.727	8.725
8.725	8.712
8.725	8.700
8.725	8.700
8.712	8.700
8.725	8.712
8.725	8.725
8.725	8.712
8.712	8.712
8.725	8.725
8.712	8.700
8.712	8.725
8.725	8.725
8.725	8.725
8.725	8.712
8.712	8.712
8.725	8.712
8.725	8.725
8.712	8.725
8.712	8.725
8.725	8.725
8.725	8.725
8.725	8.725
8.712	8.700
8.712	8.712
8.725	8.725

STEEL BALL # 4

180	90
7.150	7.137
7.150	7.137
7.150	7.125
7.150	7.125
7.150	7.125
7.150	7.187
7.162	7.150
7.162	7.150
7.150	7.150
7.150	7.125
7.150	7.137
7.150	7.137
7.162	7.150
7.150	7.137
7.150	7.150
7.162	7.137
7.150	7.125
7.150	7.150
7.150	7.125
7.150	7.137
7.162	7.137
7.150	7.150
7.162	7.150
7.150	7.150
7.100	7.150

TORIC STANDARD

7.700	@94.7	7.575	@145.9
7.725	@92.3	7.575	@148.8
7.700	@93.5	7.562	@145.1
7.700	@96.9	7.562	@146.3
7.712	@93.2	7.575	@145.0
7.725	@94.0	7.612	@139.0
7.712	@93.6	7.612	@142.3
7.712	@93.6	7.625	@141.0
7.725	@93.6	7.600	@142.0
7.725	@91.0	7.587	@142.0
7.725	@89.0	7.575	@142.2
7.712	@90.4	7.587	@145.0
7.725	@93.8	7.575	@143.0
7.712	@93.1	7.575	@141.2
7.725	@95.5	7.600	@137.6
7.712	@91.0	7.550	@144.2
7.712	@90.4	7.550	@143.0
7.725	@92.5	7.575	@143.0
7.737	@93.1	7.575	@141.2
7.725	@94.5	7.600	@139.6
7.725	@92.0	7.587	@144.4
7.725	@93.2	7.575	@140.6
7.712	@93.7	7.600	@140.5
7.700	@94.0	7.575	@143.4
7.725	@94.5	7.600	@141.6

ORGANIZATION OF STATISTICS

Examiner #1		Examiner #2	
Human Cornea #1			
Mean	Standard Deviation	Mean	Standard Deviation
7.86 mm	0.01 mm	7.86 mm	0.026 mm
174.4°	1.90°	172.7°	1.05°
8.21 mm	0.014 mm	8.21 mm	0.014 mm
93.7°	2.21°	93.9°	2.31°
Human Cornea #2			
7.77 mm	0.01 mm	7.78 mm	0.01 mm
9.68°	2.1°	12.2°	1.84°
7.11 mm	0.01 mm	7.15 mm	0.01 mm
94.1°	1.36°	94.2°	1.26°
Human Cornea #3			
7.72 mm	0.01 mm	7.65 mm	0.01 mm
178.3°	1.86°	179.8°	2.07°
6.96 mm	0.01 mm	6.94 mm	0.01 mm
82.6°	1.61°	82.5°	1.75°
Human Cornea #4			
7.63 mm	0.0001 mm	7.62 mm	0.014 mm
175.4°	1.11°	176.9°	1.44°
7.04 mm	0.0001 mm	7.01 mm	0.01 mm
78.1°	1.41°	75.9°	2.01°

Human Cornea #5

7.66 mm	0.0001 mm	7.65 mm	0.01 mm
4.56°	1.12°	5.5°	1.56°
6.97 mm	0.0001 mm	6.97 mm	0.02 mm
87.5°	1.30°	86.4°	1.38°

Human Cornea #6

8.23 mm	0.014 mm	Examiner #2 subject
2.2°	1.01°	
7.45 mm	0.02 mm	
84.9°	1.82°	

Human Cornea #7

8.20 mm	0.01 mm	Examiner #2 subject
177.4°	0.87°	
7.22 mm	0.02 mm	
81.9°	1.65°	

Steel Ball #1

8.31 mm @ 180°	0.0001 mm	8.32 mm	0.0001 mm
8.31 mm @ 90°	0.0001 mm	8.32 mm	0.0001 mm

Steel Ball #2

7.53 mm @ 180°	0.0001 mm	7.52 mm	0.0001 mm
7.52 mm @ 90°	0.0001 mm	7.54 mm	0.0001 mm

Steel Ball #3

8.72 mm @ 180°	0.0001 mm	8.72 mm	0.0001 mm
8.72 mm @ 90°	0.01 mm	8.73 mm	0.0001 mm

Steel Ball #4

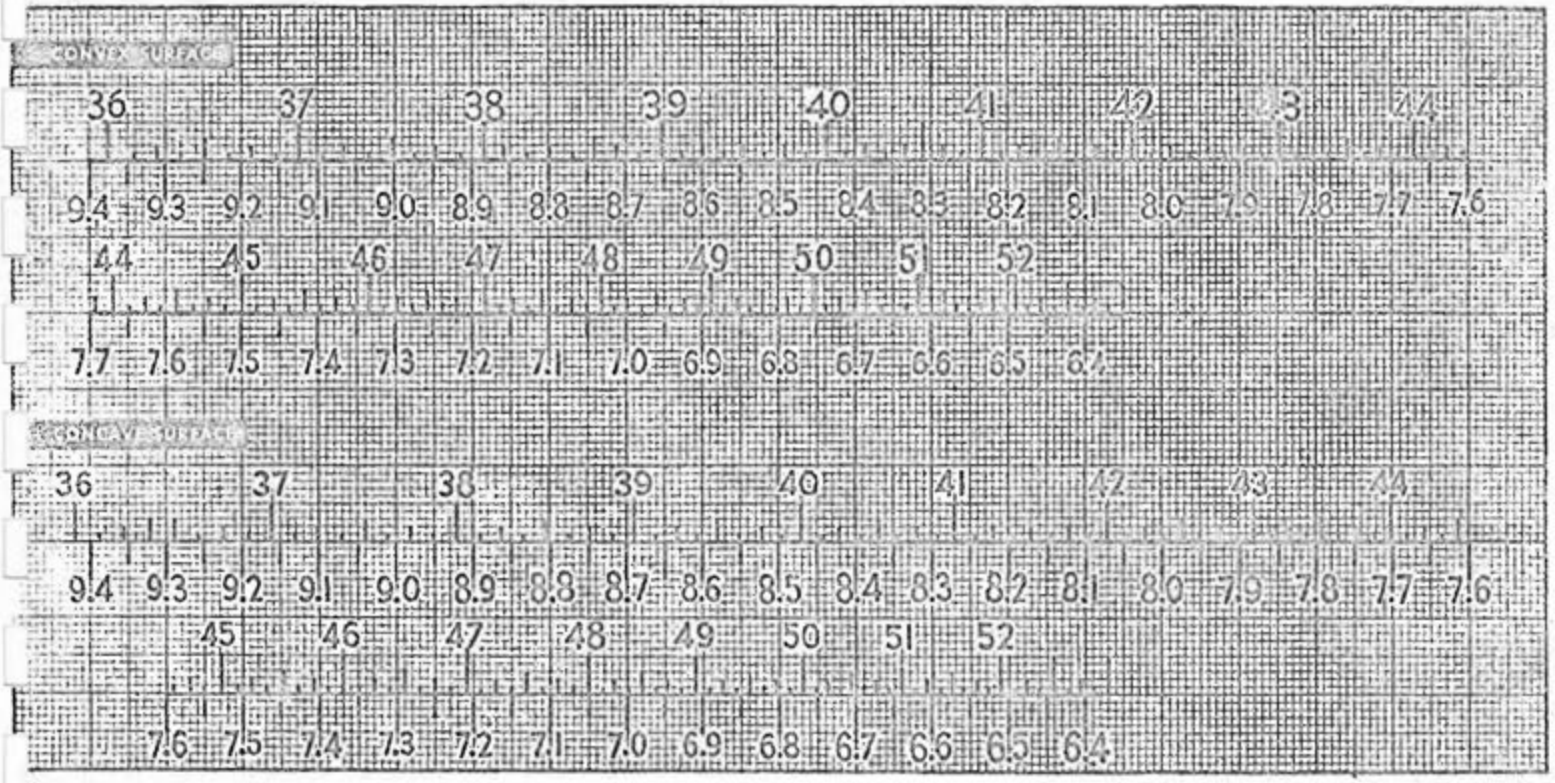
7.12 mm @ 180°	0.0001 mm	7.15 mm	0.0001 mm
7.13 mm @ 90°	0.0001 mm	7.14 mm	0.0001 mm

Toric Standard

7.58 mm	0.01 mm	7.58 mm	0.01 mm
144.9°	2.29°	142.6°	2.60°
7.70 mm	0.0001 mm	7.72 mm	0.0001 mm
89.4°	3.25°	91.6°	1.82°

DIOPTERS AND RADII SCALE
For Keratometer

The scales on the measurement drums of the B&L Keratometer record the diopter value of the curve being measured, to nearest eighth diopter. The Conversion Charts below translate these readings into the equivalent radii of curvature, convex or concave, to the nearest hundredth of a millimeter.



712135-319ND, 1500, XI-60

PRINTED IN U. S. A.

Above values for dioptric power are based on an assumed refractive index for corneal tissue of 1.3375.

Example:

Given: Keratometer reading = 42.50 D

$$r = \frac{n'-n}{p} = \frac{1.3375-1.0000}{42.50} = \frac{0.3375}{42.50}$$

$r = 7.94 \times 10^{-3}$ meters

r= 7.94 millimeters convex radius

Note: When measuring the concave surface of a contact lens, a correction factor must be used (see table above).

POWER-RADIUS CONVERSION TABLE

D	R	D	R	D	R
30.00	11.250	36.00	9.375	42.00	8.036
30.12	11.203	36.12	9.343	42.12	8.012
30.25	11.157	36.25	9.310	42.25	7.988
30.37	11.111	36.37	9.278	42.37	7.965
30.50	11.066	36.50	9.247	42.50	7.941
30.62	11.020	36.62	9.215	42.62	7.918
30.75	10.976	36.75	9.184	42.75	7.895
30.87	10.931	36.87	9.153	42.87	7.872
31.00	10.887	37.00	9.122	43.00	7.849
31.12	10.843	37.12	9.091	43.12	7.826
31.25	10.800	37.25	9.060	43.25	7.803
31.37	10.757	37.37	9.030	43.37	7.781
31.50	10.714	37.50	9.000	43.50	7.759
31.62	10.672	37.62	8.970	43.62	7.736
31.75	10.630	37.75	8.940	43.75	7.714
31.87	10.588	37.87	8.911	43.87	7.692
32.00	10.543	38.00	8.882	44.00	7.670
32.12	10.506	38.12	8.852	44.12	7.649
32.25	10.465	38.25	8.824	44.25	7.627
32.37	10.425	38.37	8.795	44.37	7.606
32.50	10.385	38.50	8.766	44.50	7.584
32.62	10.345	38.62	8.738	44.62	7.563
32.75	10.305	38.75	8.710	44.75	7.542
32.87	10.266	38.87	8.682	44.87	7.521
33.00	10.227	39.00	8.654	45.00	7.500
33.12	10.189	39.12	8.526	45.12	7.479
33.25	10.150	39.25	8.599	45.25	7.459
33.37	10.112	39.37	8.571	45.37	7.438
33.50	10.075	39.50	8.544	45.50	7.418
33.62	10.036	39.62	8.517	45.62	7.397
33.75	10.000	39.75	8.491	45.75	7.377
33.87	9.963	39.87	8.464	45.87	7.357
34.00	9.926	40.00	8.437	46.00	7.337
34.12	9.890	40.12	8.411	46.12	7.317
34.25	9.854	40.25	8.385	46.25	7.297
34.37	9.818	40.37	8.359	46.37	7.278
34.50	9.783	40.50	8.333	46.50	7.258
34.62	9.747	40.62	8.308	46.62	7.239
34.75	9.712	40.75	8.282	46.75	7.219
34.87	9.677	40.87	8.257	46.87	7.200
35.00	9.643	41.00	8.232	47.00	7.181
35.12	9.609	41.12	8.207	47.12	7.162
35.25	9.574	41.25	8.182	47.25	7.143
35.37	9.541	41.37	8.157	47.37	7.124
35.50	9.507	41.50	8.133	47.50	7.105
35.62	9.474	41.62	8.108	47.62	7.087
35.75	9.441	41.75	8.084	47.75	7.068
35.87	9.408	41.87	8.060	47.87	7.050

D	R	D	R	D	R
48.00	7.031	54.00	6.250	60.00	5.625
48.12	7.013	54.12	6.236	60.12	5.613
48.25	6.995	54.25	6.221	60.25	5.602
48.37	6.977	54.37	6.207	60.37	5.590
48.50	6.959	54.50	6.193	60.50	5.579
48.62	6.941	54.62	6.178	60.62	5.568
48.75	6.923	54.75	6.164		
48.87	6.905	54.87	6.150		
49.00	6.888	55.00	6.136		
49.12	6.870	55.12	6.122		
49.25	6.853	55.25	6.109		
49.37	6.835	55.37	6.095		
49.50	6.818	55.50	6.081		
49.62	6.801	55.62	6.067		
49.75	6.784	55.75	6.054		
49.87	6.767	55.82	6.040		
50.00	6.750	56.00	6.027		
50.12	6.733	56.12	6.013		
50.25	6.716	56.25	6.666		
50.37	6.700	56.37	5.987		
50.50	6.683	56.50	5.973		
50.62	6.667	56.62	5.960		
50.75	6.650	56.75	5.947		
50.87	6.634	56.87	5.934		
51.00	6.618	57.00	5.921		
51.12	6.601	57.12	5.908		
51.25	6.585	57.25	5.895		
51.37	6.569	57.37	5.882		
51.50	6.553	57.50	5.870		
51.62	6.538	57.62	5.857		
51.75	6.522	57.75	5.844		
51.87	6.506	57.87	5.832		
52.00	6.490	58.00	5.819		
52.12	6.475	58.12	5.806		
52.25	6.459	58.25	5.794		
52.37	6.444	58.37	5.782		
52.50	6.429	58.50	5.769		
52.62	6.413	58.62	5.757		
52.75	6.398	58.75	5.745		
52.87	6.383	58.82	5.732		
53.00	6.368	59.00	5.720		
53.12	6.353	59.12	5.708		
53.25	6.338	59.25	5.696		
53.37	6.323	59.37	5.684		
53.50	6.308	59.50	5.672		
53.62	6.294	59.62	5.660		
53.75	6.279	59.75	5.649		
53.87	6.264	59.87	5.637		

CONCLUSION

Upon comparing the measurements there seemed to be an insignificant amount of variability between the two examiners. Because of this, we have grouped all the data together.

The average standard deviation for both examiners on all the human corneas in both meridians is .0109 mm. For a medium with an index of 1.337 (like the cornea), a .1000 mm difference in curvature is equal to approximately .55D. Taking this into consideration, this means that 68 percent of all the measurements taken in a particular meridian will have a range of not over .11D and that 95 percent of all the measurements will have a range not exceeding .22D. This, of course, is excellent reliability and would allow a practitioner, after averaging perhaps five measurements, to know that he has an extremely accurate set of findings.

As would be expected, the average standard deviations on the steel balls and toric standard were even lower than on the human cornea. For the steel balls it was .0016 mm and .0051 mm for the toric standard. There seems to be no difference in reliability between the two principal meridians.

However, in order to get reliable corneal radius

findings, it is imperative to be on the principal meridians. Looking at the standard deviation of degree values of the principal meridians, it is seen that they are quite low. These, of course, will tend to be proportional to the amount of toricity of the cornea, that is, the greater the toricity, the easier it is to find the principal meridans.

We have already mentioned some of the outstanding characteristics of the instrument, such as, ease of operation, clarity of mires, etc., but having demonstrated such excellent reliability, we are even more impressed with the Gamb's Ophthalmometer than we were at the beginning of the study. Although it is more expensive than other commonly used instruments, for taking corneal radius findings we would highly recommend a Gamb's Ophthalmometer for anyone who lacks confidence in the instrument they are currently using.

Our results show, the Gamb's Ophthalmometer is much more reliable than any of the instruments used by a practitioner in the field.

Brungardt's experiment, for example, has shown that the B&L Keratometer has a range of reliability of 0.37D for the horizontal reading and 0.75D for the vertical.

Therefore, in comparing the B&L Keratometer, the usual instrument for taking corneal radius measurements

by practitioners, with the Gamb's Ophthalmometer, the Gamb's instrument is superior.