A Comparison of the Humphrey Autokeratometer and System 2000 with the Bausch and Lomb Keratometers

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Abstract

A series of clinical evaluation tests were performed to compare the performance of the Humphrey Model 410 Autokeratometer and Wesley Jessen System 2000 with a conventional Bausch & Lomb keratometer considered as a reference standard. Both of these semi-automated instruments seemed to give consistent, reliable, and accurate results relative to the conventional keratometer; despite its much higher cost, the autokeratometer however appears to be the most practical instrument in a large practice because of the very high speed with which results are printed out.

Abrégé

Une série d'essais cliniques furent entrepris en vue de comparer les caractéristiques de l'Autokératomètre Humphrey modèle 410 et du système 2000 de Wesley Jessen avec celles d'un kératomètre conventionnel Bausch & Lomb considéré comme instrument de référence. Ces deux instruments semi-automatiques semblent donner des résultats qui sont consistents, fiables, et précis relativement à ceux obtenus avec un kératomètre conventionnel; malgré son coût plus élevé, l'autokératomètre semble être un instrument très pratique dans un bureau achalandé vu sa tres grande rapidité à imprimer les résultats.

Objective

The objective of this study was to perform a clinical comparison of the Humphrey Autokeratometer and System 2000 with the Bausch & Lomb keratometer, using a total of 12 human subjects. The primary instrumental parameters considered were their consistency and reliability, accuracy, speed, and ease of operation.

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Three instruments were used in this study:

1. A Bausch & Lomb keratometer.

This standard instrument[1] was modified by adding two small red fixation targets on the Jessop ring fitted in the front of the instrument to define nasal and temporal fixation points at 13.5° on each side of the central fixation point. These corresponded to the same central and peripheral fixation points used by the Humphrey autokeratometer.

2. A Humphrey Model 410 Autokeratometer.

This comparatively new computer-control-lid instrument[2] can rapidly obtain a print out of the following basic information for each (or either) eye, as illustrated in the sample output in Figure 1:

a. Central keratometry values: dioptric power, corneal radius, and axis along the two principal meridians; corneal astigmatism and axis of the cylinder.
b. Apical keratometry values: dioptric power, corneal radius, and axis along the two principal meridians; corneal astigmatism and axis of the cylinder.
c. Shape factor: the number that indicates the rate of corneal flattening from the apex along the horizontal meridian.
d. Apex position: this gives the position of the apex relative to the visual axis, superior or inferior, and temporal or nasal.
e. Vault height: this gives the height of the apex above the extended scleral surface.
f. Conformance factor: this is a number that indicates the degree of correlation between the actual corneal measurements taken and the Humphrey model of the cornea.

In addition to all the above information, keratometry values for the nasal and temporal peripheral corneas are also displayed on a video terminal but are not printed out. These readings are taken using special fixation lights to locate, in turn, the central, temporal, and nasal corneas along the horizontal meridian.

3. A Wesley-Jessen System 2000

This instrument is an advanced photokerato-

scope[3,4] capable of measuring the corneal topography through the use of photography in conjunction with computer technology. The basic optical principle is identical to that used in a conventional keratometer, that is observation of the relationship between a given size target and the size of that target virtual image formed by the cornea acting as a convex mirror.

The output information comes in the form of a computer print-out which includes the following data:

a. Central keratometry values: corneal radius along the two principal meridians, "read" angle; the "read" style is the angle at which the keratograph is oriented when measured.
b. Apex position: this gives the distance and orientation of the apex relative to the visual axis.
c. Shape factor: similar to the Humphrey autokeratometer output, this is a number that indicates the rate of corneal flattening along a meridian; with the System 2000, however, two shape factors are given for each eye, corresponding respectively to the two principal meridians.
d. Peripheral curves: the actual amounts (in millimeters) by which the measured cornea is anterior or posterior to the Wesley-Jessen model cornea, along the two principal meridians. In contrast to the Humphrey autokeratometer, however, the System 2000 does not provide the actual peripheral dioptic values (or peripheral corneal radii).
e. Contact lens design parameters: the measured corneal data is used in conjunction with the patient's spectacle prescription, to obtain all the parameter required to fabricate hard lenses.

A sample computer print-out is reproduced in Figure 2.

Experiment design

All 12 subjects used in the experiment were in good ocular health and were either emmetropes or low ametropes. The following experiments were performed to determine:

1. Consistency of the Humphrey Autokeratometer.

A number of independent sets of readings were taken in quick succession on two different subjects to test the repeatability and reliability of the results and compute the standard deviations. A similar test of the System 2000 was not done due to cost limitations (a new polaroid photograph must be taken and processed in each case).

2. Comparison of the Humphrey Autokeratometer and System 2000 with the Bausch & Lomb keratometer.

Readings were taken on ten subjects using the Bausch & Lomb keratometer, the Humphrey Autokeratometer, and the System 2000. Since the Autokeratometer had been previously shown to give consistent results, only one set of observations was taken on each subject with that instrument. Three sets of readings were however taken on each subject with the Bausch & Lomb instrument and were averaged out. Some of the subjects also had previous clinical records (including keratometric values) at the clinic of the School of Optometry and this data was also utilized.

Next, the instruments were compared by computing, in each case, the differences "Δ" between keratometric and axis values obtained by the B&L keratometer, the System 2000, and the Autokeratometer. Finally the means and standard deviations of these differences were computed.

Results

1. Consistency of the Humphrey Autokeratometer.

These are presented in Table 1, from which the following summary conclusions may be drawn:

a. This instrument seems to be very good in giving consistent central or apical corneal curvatures: the average dioptric standard deviation was only about ±0.09D, which is less than ±0.12D. In only one case was the standard deviation greater than ±0.25D, or ±0.31D.
b. The computed corneal astigmatism was equally consistent with an average dioptric standard deviation of about ±0.09D.
c. The consistency of the axis determination of the corneal cylinder appears to be more variable, with the standard deviation ranging between a minimum of ±2° and a maximum of ±72° with an average of ±40°. These high values are however of no clinical significance, since they refer to cases where the corneal astigmatism is small (0.50D or less) and would typically be ignored in contact lens fitting. In the only case where the corneal astigmatism was approaching 1.00D, the standard deviation for axis determination was ±3° for the apical region and ±7° for the central region.
d. The consistency of the other parameters measured or computed (shape factor, apex location, tolerance, vault height, conformance factor) appeared to be equally good; for instance, the average standard deviation of the shape factor is about ±0.03, or about ±10% of the average value.

2. Comparison of the Humphrey Autokeratometer and System 2000 with the Bausch & Lomb keratometer.

These are presented in Tables 2 and 3, from which the following summary conclusions may be drawn:

a. Over the central cornea, the results obtained with the Humphrey Autokeratometer agree more closely with those of the B & L keratometer than those of the System 2000; relative to the B & L keratometer readings, the Autokeratometer readings are slightly higher (by less than

0.25D), while the System 2000 readings are higher still (by about 0.50D).

b. Over various regions of the horizontal meridian, the Humphrey Autokeratometer and the B & L keratometer results agree most closely over the central cornea (difference of less than 0.25D) and least closely over the nasal periphery (difference close to 1.00D), with the temporal periphery values difference being in between (slightly larger than 0.50D).

c. It is more difficult to compare the accuracy of the three instruments relative to axis determination for corneal astigmatism, since most subjects under study had comparatively little corneal astigmatism: of the 20 eyes examined, only 5 had one dioptre or more of central corneal astigmatism, and none had more than 1.5D. The other 15 all had less than 1.00D of astigmatism and the precise determination of the axis in these cases is not too important since such a small amount of corneal astigmatism would commonly be ignored in clinical contact lens fitting. If we however restrict ourselves to those cases with 1.0D or more of astigmatism, the following conclusions may be given:

(1) Central corneal measurements. The results of the Humphrey Autokeratometer and the B&L keratometer seem to agree closely, with an axis difference of less than 10° in all case, while those of the System 2000 seem to be much less accurate, with an axis difference of about 60° - 70° relative to the B&L keratometer.

(2) Peripheral corneal measurements. The average axis difference between the Autokeratometer and the B&L keratometer findings appears to be about 15° - 20°. Hence again, the System 2000 is much less accurate.

Summary

A table summarizing the main features, advantages, and disadvantages of each instrument is given in Table 4.

Acknowledgement

We wish to thank Carl Zeiss Canada for the use of the Humphrey Autokeratometer and Plastic Contact Lens Company (Canada) Ltd. for supporting this study.

References

1. Keratometer Instructions, Cat. No. 71-21-35, Bausch & Lomb, Incorporated.
2. Owner's Manual, Model 410 Autokeratometer Manual, Humphrey Instruments Incorporated.
3. System 2000 Guide, Rx Input Data and Printout, Wesley-Jessen Inc.
4. Instructions, PEK Mark III Photo-Electric Keratoscope, Catalog #298-10, Wesley-Jessen Inc.

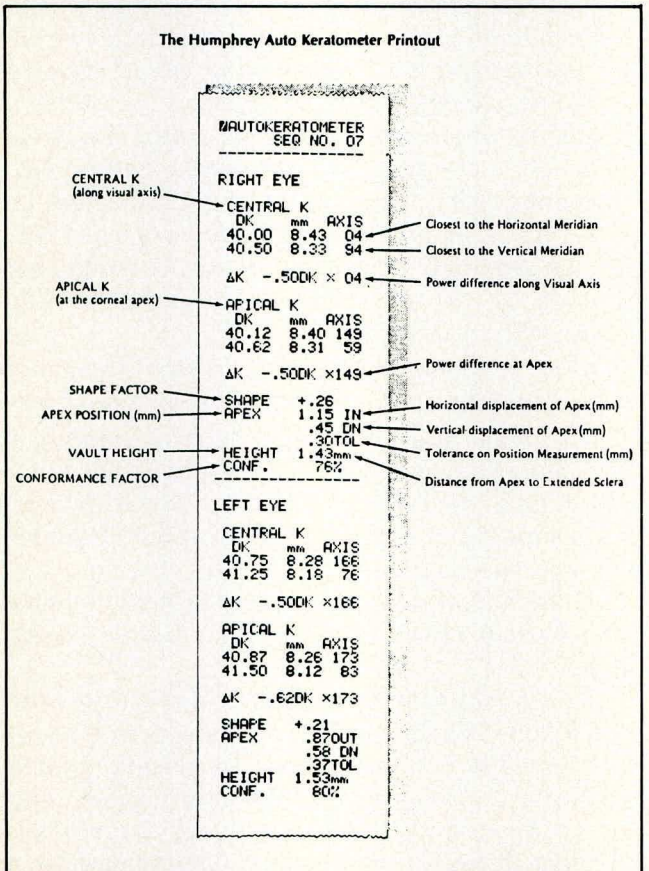

Figure 1 — Sample output print-out of the Humphrey Auto keratometer

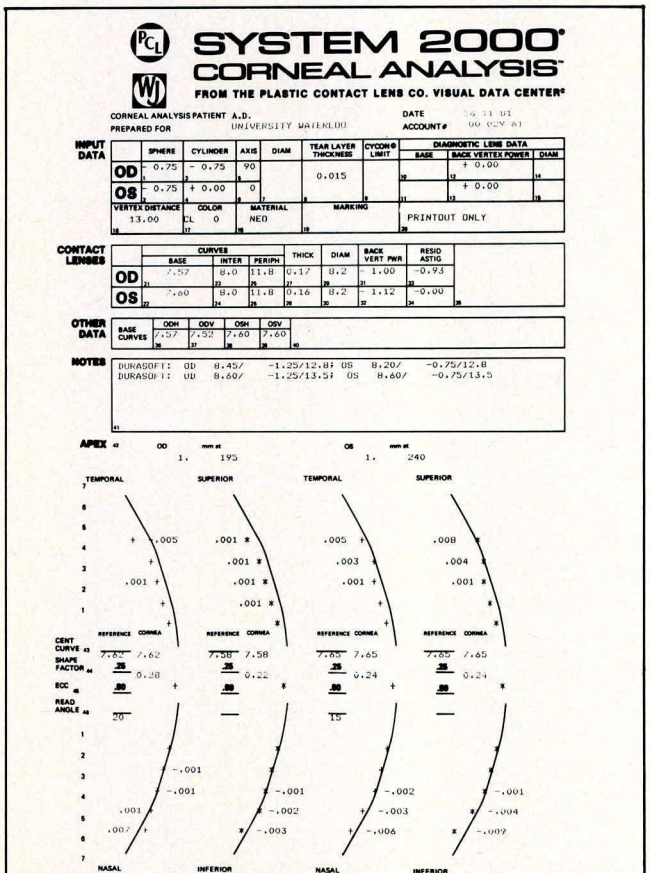

Figure 2. Sample output print-out of the System 2000.

Subject	G.Y.M.		D.D.S.	
	Averages of 4 measurements	Standard derivation	Average of 3 measurements	Standard derivations
OD Central K	42.50 @ 148	0.00/017	42.17 @ 096	0.31/014
	42.25 @ 058	0.09/017	42.04 @ 006	0.06/014
△K	-0.25 X 058	0.09/017	-0.13 X 006	0.31/014
Apical K	42.81 @ 138	0.06/008	42.67 @ 102	0.12/002
	42.50 @ 048	0.06/008	42.17 @ 012	0.12/002
△K	-0.31 X 048	0.06/008	-0.50 X 012	0.00/002
Shape factor	+0.37	+0.03	+0.24	0.03
Apex location	0.40 out	0.05 out	0.71 out	0.11 out
	0.72 down	0.11 down	0.73 down	0.37 down
Tolerance	0.20	0.02	0.32	0.05
Vault height	1.37 mm	0.03 mm	1.51 mm	0.04 mm
Conf. factor	89%	4%	77%	7%
OS Central K	42.06 @ 162	0.06/070	42.54 @ 084	0.16/007
	41.65 @ 072	0.06/024	41.62 @174	0.00/007
△K	-0.41 X 072	0.06/024	-0.92 X 174	0.15/007
Apical K	42.28 @ 150	0.10/072	42.75 @ 080	0.10/003
	42.06 @ 060	0.06/031	41.87 @ 170	0.10/003
△K	-0.22 X 060	0.06/031	-0.87 X 170	0.00/003
Shape factor	+0.33	0.01	+0.32	0.05
Apex location	0.4 out	0.05 out	0.77 out	0.07 out
	0.98 down	0.25 down	0.59 down	0.09 down
Tolerance	0.23	0.01	0.24	0.04
Vault height	140 mm	0.01 mm	1.41 mm	0.18
Conf. factor	87%	5%	90%	3%

Table 1 — Consistency of the Humphrey Autokeratometer when taking repeated measurement on the same subjects.

Subject	Eye	Location	(1) B&L Keratometer K values	Axis	(2) System 2000 K values	Axis	(3) Autokeratometer K values	Axis	(2) - (1) △ K values	△ Axis	(3) - (1) △ K values	△ Axis	(3) - (2) △ K values	△ Axis
		Central	40.43/41.06	090	40.81/41.72	020	40.25/41.00	124	0.38/0.66	-070	-0.18/-0.06	034	-0.56/-0.72	104
	OD	Temporal	40.37/40.54	065			41.12/40.62	049			0.75/0.08	-016		
D.L.		Nasal	38.21/40.21	087			38.62/40.75	106			0.41/0.54	-019		
		Central	40.87/41.25	090	41.26/41.41	030	40.87/41.25	049	0.39/0.16	-060	0.00/0.00	-041	0.61/-0.16	019
	OS	Temporal	40.29/40.50	040			40.87/41.00	094			0.58/0.50	054		
		Nasal	39.04/40.25	060			39.50/41.12	072			0.46/0.87	012		
		Central	45.25/45.50	090	45.55/45.73	020	45.87/45.00	128	0.30/0.23	-070	0.62/-0.50	038	0.32/-0.73	108
	OD	Temporal	44.46/44.46	030			45.00/45.50	049			0.54/1.04	019		
M.G.		Nasal	43.00/44.16	060			44.37/45.00	083			1.37/0.84	023		
		Central	45.25/45.50	090	45.79/45.92	020	45.00/45.37	097	0.54/0.42	-070	-0.25/-0.13	007	-0.79/-0.55	077
	OS	Temporal	44.50/44.54	065			45.12/45.50	112			0.62/0.96	047		
		Nasal	43.67/44.29	066			44.62/45.00	094			0.95/0.71	028		
		Central	43.43/44.06	090			43.62/44.12	106			0.19/0.06	016		
	OD	Temporal	42.62/43.62	063			43.25/44.25	075			0.63/0.63	012		
D.B.		Nasal	42.25/42.91	065	Not		42.62/44.12	103	Not		0.37/1.21	038	Not	
		Central	43.37/43.94	090	Available		43.50/44.12	099	Available		0.13/0.18	009	Available	
	OS	Temporal	43.04/43.41	065			43.25/44.37	113			0.21/0.96	048		
		Nasal	41.75/43.17	065			42.62/44.00	082			0.87/0.83	017		
		Central	42.50/43.25	090	43.10/43.83	025	42.50/43.37	090	0.60/0.58	-065	0.00/0.12	000	-0.60/-0.46	065
	OD	Temporal	Not Available				41.75/43.37	082			Not Available			
G.B.		Nasal					41.62/43.37	098						
		Central	42.87/43.50	110	43.60/44.23	030	42.87/43.50	111	0.73/0.73	-080	0.00/0.00	001	-0.73/-0.73	081
	OS	Temporal	Not Available				42.00/43.37	128			Not Available			
		Nasal					42.37/44.25	090						
		Central	45.50/47.00	090	46.36/47.20	020	45.62/47.50	097	0.86/0.20	-070	0.12/0.50	007	-0.74/0.30	077
	OD	Temporal	44.50/46.00	090			44.62/46.37	081			0.12/0.37	-009		
S.K.		Nasal	44.25/46.25	090			44.75/47.00	101			0.50/0.75	011		
		Central	44.87/46.00	096	45.30/46.49	020	45.37/46.37	088	0.43/0.49	-076	0.50/0.37	-008	0.07/-0.12	068
	OS	Temporal	44.25/46.00	092			44.37/46.50	096			0.12/0.50	004		
		Nasal	43.37/45.37	100			44.00/45.75	084			0.63/0.38	-016		

Table 2 — Comparison of results obtained with the B&L Keratometer, the System 2000, and the Humphrey Autokeratometer on five subjects.

Subject	Eye	Location	(1) B&L Keratometer K values	Axis	(2) System 2000 K values	Axis	(3) Autokeratometer K values	Axis	(2) - (1) △ K values	△ Axis	(3) - (1) △ K values	△ Axis	(3) - (2) △ K values	△ Axis
		Central	43.75/44.25	090	44.29/44.53	020	43.75/44.87	093	0.54/0.28	-070	0.00/0.62	003	-0.54/0.34	073
	OD	Temporal	43.16/44.08	152			43.87/44.62	088			0.71/0.54	-064		
A.D.		Nasal	42.42/42.58	149			43.87/44.62	090			1.45/2.04	-059		
		Central	43.50/44.00	110	44.12/44.12	015	43.75/44.12	106	0.62/0.12	-095	0.25/0.12	-004	-0.37/0.00	091
	OS	Temporal	43.21/43.37	075			43.37/44.50	116			0.16/1.13			
		Nasal	41.00/42.91	080			42.50/43.75	110			1.50/0.84	030		
		Central	40.75/42.25	090	41.31/42.24	025	40.87/42.25	097	0.56/-0.01	-065	0.12/0.00	007	-0.44/0.01	072
	OD	Temporal	40.08/41.79	082			40.62/41.75	089			0.54-0.04	007		
B.P.	Nasal	39.50/41.21	080				39.87/42.00	100			0.37/0.79	020		
		Central	41.00/42.00	090	41.77/42.51	015	41.12/42.50	089	0.77/0.51	-075	0.12/0.50	-001	-0.65/-0.01	074
	OS	Temporal	40.66/41.58	067			40.87/42.87	101			0.21/1.29	034		
		Nasal	38.58/41.41	078			40.25/42.50	082			1.67/1.09	004		
		Central	42.87/42.87	—	43.77/43.95	020	43.00/42.87	092	0.90/1.08	—	0.12/0.00	—	-0.77/-1.8	072
	OD	Temporal	42.33/41.32	051			43.37/42.75	132			1.04/1.43	081		
		Nasal	41.83/41.92	047			42.25/43.00	119			0.42/1.08	072		
B.M.		Central	43.00/43.12	090	43.22/43.32	025	43.00/43.12	117	0.22/0.20	-065	0.00/0.00	027	-0.22/-0.20	092
	OS	Temporal	42.29/42.71	072			42.62/43.37	114			0.33/0.66	042		
		Nasal	41.41/42.29	065			42.00/42.87	065			0.59/0.58	000		
		Central	44.50/44.00	090	44.71/44.47	015	44.37/44.00	070	0.21/0.47	075	-0.13/0.00	-020	-0.34/0.47	055
	OD	Temporal	43.75/43.08	040			44.25/43.50	131			0.50/0.42	091		
M.M.		Nasal	41.70/43.25	094			42.62/44.25	120			0.92/1.00	026		
		Central	44.50/44.25	090	45.49/44.35	010	44.75/43.87	048	0.99/0.10	-080	0.25/-0.38	-042	-0.26/-0.48	038
	OS	Temporal	42.79/43.37	022			44.87/42.87	049			2.08/-0.50	027		
		Nasal	42.37/43.79	065			42.75/43.87	066			0.38/0.08	001		
		Central	42.00/41.96	046	42.72/42.56	035	42.62/42.25	102	0.72/0.60	-011	0.62/0.29	056	-0.10/-0.31	067
	OD	Temporal	41.58/41.46	060			41.87/42.25	058			0.29/0.79	-002		
M.P.		Nasal	41.41/41.62	085			42.12/42.50	094			0.71/0.88	009		
		Central	42.92/41.79	087	42.72/42.94	045	43.37/41.87	073	-0.20/-1.15	-042	0.45/0.08	-014	0.65/-1.07	028
	OS	Temporal	42.45/41.54	090			43.00/41.75	064			0.55/0.21	-026		
		Nasal	42.50/41.79	090			43.12/42.12	079			0.62/0.33	-011		

Table 3 — Comparison of results obtained with the B&L Keratometer, the System 2000, and the Humphrey Autokeratometer on five subjects.

Characteristic	Humphrey Autokeratometer	Wesley-Jessen System 2000	Bausch & Lomb Keratometer
Cost	$13,500.	$2,995.	$1,300.
Size, etc.	Slightly larger than keratometer; requires a table or stand	Slightly larger than keratometer; requires a table or stand	Compact; mounted on standard instrument stand
Versatility	Limited; output information obtained is for the horizontal meridian only.	Limited; output information is given on a standard computer printout. Peripheral dioptric values are not given.	Wide; central and any peripheral area of the cornea may be measured at will.
Accuracy:			
1. Dioptric Power	High (about 0.25D)	Fair (about 0.50D)	High (about 0.25D)
2. Cylinder Axis	High (about 10°)	Poor (about 60°)	High (about 10°)
Output Format	Mostly automatic (computer printout), except that peripheral corneal data must be transcribed by hand	completely automatic (computer printout)	Completely manual (all data must be transcribed by hand)
Speed of Operation	Very fast (complete survey of a patient takes less than 5 minutes)	Very slow (although the keratographs are obtained quickly, they must be mailed to Wesley-Jessen for computer processing)	Variable, depending on clinical experience of operator
Objectivity/Subjectivity	Totally objective (except for gross alignment)	Totally objective (except for focussing)	Totally subjective
Other output information provided or other applications	Provides information on apical cornea and shape of cornea; may be used to measure base curve of hard contact lenses.	Provides information on apical cornea and shape of cornea; provides design parameters for best fit contact lenses.	May be used to measure base curve of hard contact lenses; may be used to detect keratoconus.

Table 4 — Summary characteristics of the Humphrey Autokeratometer, Wesley-Jessen System 2000, and Bausch & Lomb Keratometer.