A Comparison Between
Manually-Operated and Automated Lensometers

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INTRODUCTION AND PURPOSE:

With the dramatic increase in automation and computerization in the optometric profession, the practitioners, technicians and opticians are subjected to a deluge of advertisements, demonstrations and claims concerning these electronic marvels. Once the machine's impressive appearance, ease of operation, price tag and accessories are placed to one side, one logical question might be, "How accurate is it?" This is especially true in considering automated lensometers.

The major problem in trying to answer the question of accuracy in a lensometer is that there is no ultimately correct "reader" of lens power. For years the manually operated focimeter with its cross-hair target and power wheel on one side has been the standard. It's difficult to say that this instrument always gives the correct lens power because blur interpretation and axis orientation are subjective when using this instrument. Extrapolating in one's own mind which dioptric value the power indicator is closest to can also enter into the results.

Automated lensometers, on the other hand, remove nearly all subjective influences from lens power readings. The operator me~~e~~rly turns on the machine, places the spectacle lens to be read in the appropriate holder and pushes another button to instantly read the lens power.

Both the automated and manually operated focimeters claim to be accurate to within certain tolerances, but this matters little when trying to prove which is more accurate. As mentioned before, there is no ultimately correct machine which can tell you exactly what the power of the lens is.

Because of this, my study was designed to see what the correlation is between the manually operated lensometer and an automated lensometer. For the study I used an American Optical lensometer and a Humphrey automated lens reader. Both were located in the spectacle verification room of the FSCO clinic.

PROCEDURE:

Fifty spectacles were selected at random from the files as they arrived at the clinic for verification. Sphere power, cylinder power, cylinder axis, add power and PD were measured on each instrument in three separate trials. That is, after each complete spectacle reading, the glasses were removed from the instrument and replaced again to begin a new trial reading. The results of the three trials on the automated lensometer were averaged for each pair of glasses as they were on the manual lensometer. So, the fifty spectacles represented one hundred lenses and six hundred separate readings between the two lensometers.

P.D. measurements on each lensometer were done by finding the optical center of each lens (according to the lensometers' indications), dotting that point with the instrument's apparatus and then measuring the distance between optical centers with a millimeter rule.

Data obtained from the study has been analyzed in two ways. First, the correlation between the two instruments has been calculated based upon the average values obtained with each pair of spectacles on each lensometer. For example, the average sphere power found at the end of three trials on the A.O. lensometer was correlated with the average value found at the end of three trials on the Humphrey automated lensometer. One hundred average sphere power readings were correlated between the two instruments. The same was done for cylinder power, axis, add and P.D..

Secondly, the data was analyzed for variability within each instrument. That is, how variable were the three power readings for sphere each time the A.O. lensometer was used? How variable were the Humphrey's readings? The same variability has been analyzed for cylinder power, axis, add and P.D..

RESULTS:

Following are tables showing the results of t-tests used to assess the correlation between the A.O. lensometer and the Humphrey automated lensometer as well as the variability within each.

Sphere Power

correlation = 0.974

slope = 0.99

variability:

A.O.: t = -2.920

Humphrey: t = 0.686

For 100 degrees of freedom and 0.01 level of significance, a t score of 2.626 or above would be considered significantly variable.

Cylinder Power

correlation = 0.996

slope = 1.004

variability:

A.O.: t = -2.666

Humphrey: t = 0.677

For 100 degrees of freedom and 0.01 level of significance, a t score of 2.626 or above would be considered significantly variable.

Cylinder Axis

Correlation = 0.866

slope = .877

Variability:

A.O.: t = -4.212

Humphrey: t = -1.569

For 66 degrees of freedom and a 0.01 level of significance, a t score of 2.654 or above would be considered significantly variable.

Add Power

correlation = 0.996

slope = 0.999

variability:

A.O.: t = -0.561

Humphrey: t = -0.651

For 31 degrees of freedom and a 0.01 level of significance, a t score of 2.744 or above would be considered significantly variable.

P.D.

correlation = 0.780

slope = 0.746

variability:

A.O.: t = -1.395

Humphrey: t = -3.733

For 50 degrees of freedom and a 0.01 level of significance, a t score of 2.678 or above would be considered significantly variable.

DISCUSSION:

As can be seen from the data, the Humphrey and A.O. lensometers correlate quite well, especially in sphere, cylinder and add powers. All were 0.97 or above. The correlation is somewhat less for cylinder axis (0.866) and even lower (0.780) for the distance between optical centers of the lenses.

A look at the t score for variability of readings within each instrument leads to some interesting observations. In the three categories of sphere power, cylinder power and cylinder axis, the A.O. lensometer demonstrated significant variability of results. The Humphrey, however, showed significant variability in its measurement between optical centers of the lenses. Both instruments were fairly consistent in reading add power.

The variability within the manual lensometer results for sphere, cylinder and axis readings may well be due to operator interpretation of blur (power) and whether the target lines appeared to be exactly aligned (axis). Fluctuations in accommodation and in the bracketing technique of focusing may also have affected the results.

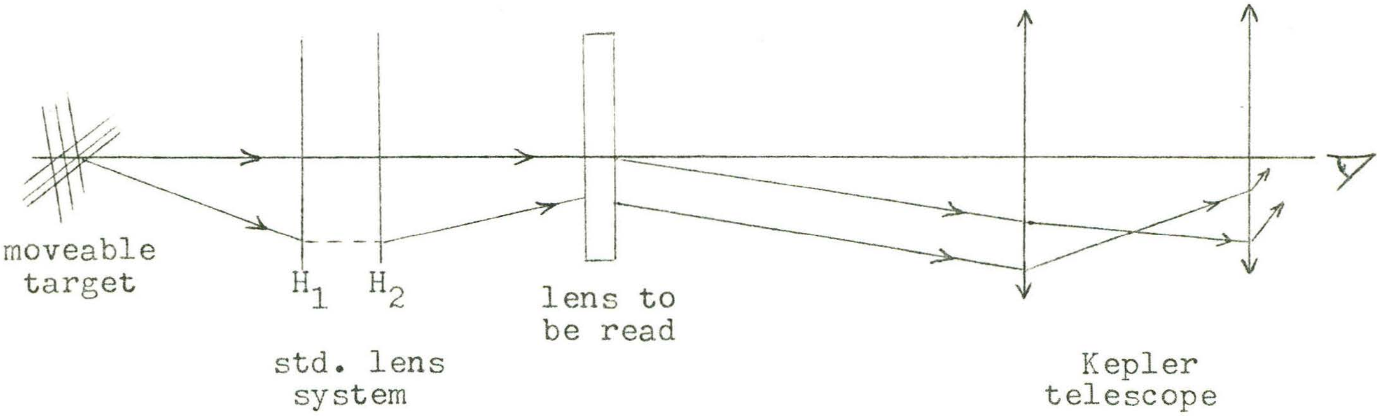
The Humphrey's variability in P.D. measurement was probably due to the manner in which the machine directed the operator to find the optical center of the lens. The readout panel continuously monitored induced prism which centering the lens, but had a lag between indicating induced BO or BI. That is, when the lens approached the optical center, there was some slight movement permitted around it where the lensometer would indicated zero prism. Bracketing between BO and BI readings was done in order to approximate the optical center, which was then dotted.

CONCLUSION:

Automated lensometers, as well as other computerized instruments, have entered the optical market with dramatic speed. The Humphrey automated lensometer seems to correlate well with the manually operated AO lensometer which has been on the market for many years. There does seem to be some discrepancy between the two on cylinder axis and PD measurements, though. Whether one is right and the other wrong remains to be proven. The practitioner must choose the instrument he believes to be right for his practice needs and goals.

Technical description of the basic operating principles of a manual lensometer:

Manually operated lensometers consist of a moveable trans-illuminated hatched target, a standard lens system of known power, and a Kepler telescope. The lens to be read is placed at the posterior focal point (F_2) of the standard lens system. Light passes through the standard lens system, the unknown lens and into the Kepler telescope. The object of the system is to get plane waves leaving the unknown lens and entering the telescope. The telescope will then focus the plane waves to give an internal image. If the internal image is blurred (i.e. plane waves are not incident upon the telescope), then a wheel on the side of the instrument is turned. This will move the instrument's target and change the vergence of light incident on the standard lens system until plane waves leave the lens of unknown power. Lens power is then read from the power wheel. This procedure is followed for both major power meridians of a cylindrical lens.

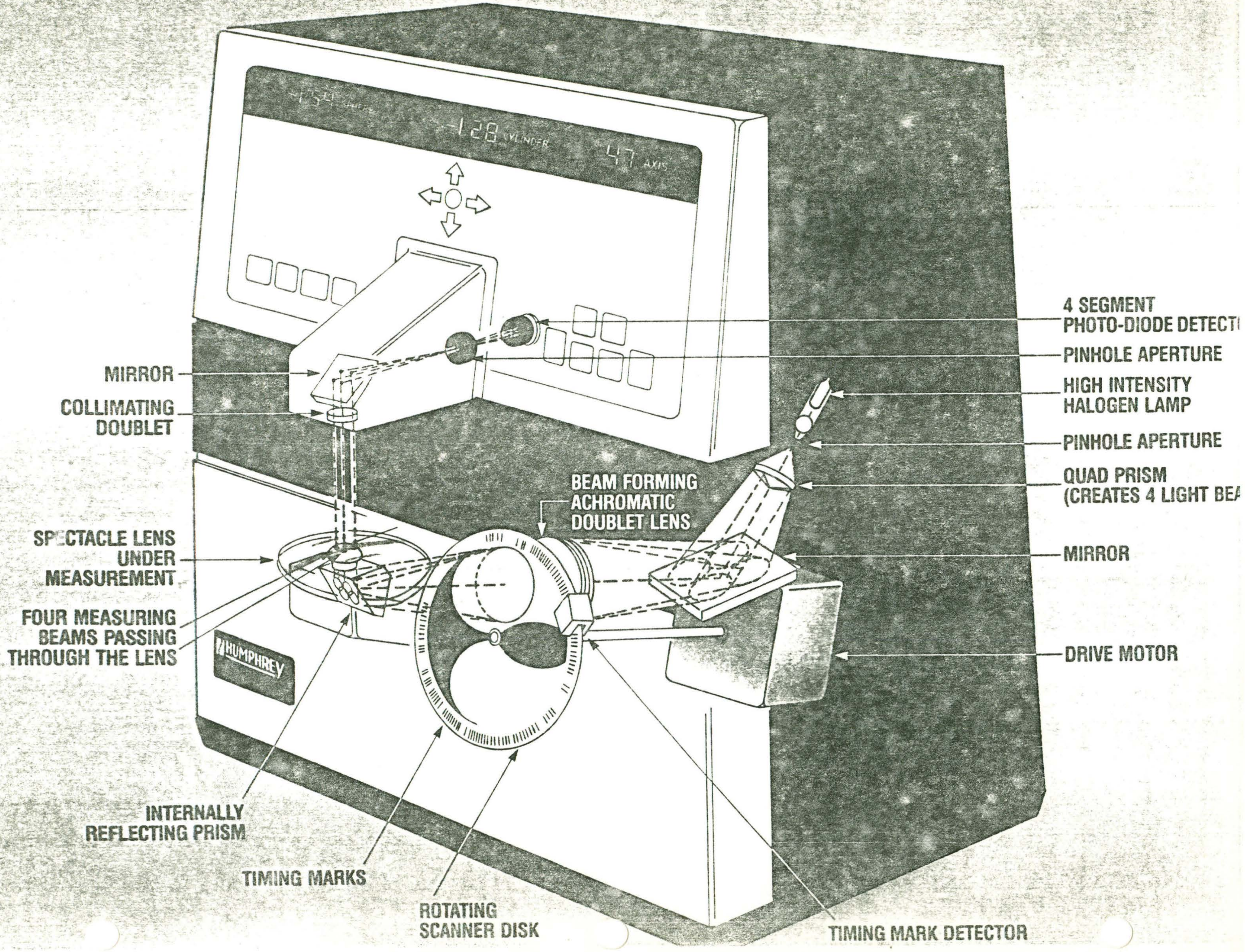


Technical description of the basic operating principles of the Humphrey Lens Analyzer:

A halogen bulb forms a light source for the first beam-forming element of the system -- a quad prism. This prism splits the light source into four beams of light which are directed by a totally reflecting mirror through an achromatic doublet lens which focuses them to give them a uniform optical quality. The beams then pass through a rotating scanner disk, or "chopper", which allows selected rays to be isolated from the continuous incoming beams. The disk is based upon an archimedian spiral and the position of the individual rays is related to the switching mechanism of the detector by timing marks on the disk.

The focused beams pass through the chopper into another prism which redirects them upward. The beams pass through a reading head and then through the lens to be read. The curvature and prism of the lens being measured causes the beams to deflect. These deflected beams then go through another doublet and are reflected onto a screen with a pinhole aperture.

Only select rays can go through the pinhole and these rays are focused onto a four segment photo-diode detector. By sensing the existence of a ray on the detector and knowing the axial displacement of that ray at the chopper, spherical, cylindrical and prismatic power information is obtained. This information and the information from the other three beams is transmitted to the internal computer of the lens analyzer. From this, the final sphere, cylinder, prism and axis for the lens is calculated and then displayed on the front display board of the instrument. All in less than one second.


-4.54
-1.28 CYLINDER
47 AXIS
HUMPHREY
4 SEGMENT PHOTO-DIODE DETECT
PINHOLE APERTURE
MIRROR
HIGH INTENSITY HALOGEN LAMP
COLLIMATING DOUBLET
PINHOLE APERTURE
QUAD PRISM (CREATES 4 LIGHT BE
BEAM FORMING ACHROMATIC DOUBLET LENS
SPECTACLE LENS UNDER MEASUREMENT
MIRROR
FOUR MEASURING BEAMS PASSING THROUGH THE LENS
DRIVE MOTOR
INTERNALLY REFLECTING PRISM
TIMING MARKS
ROTATING SCANNER DISK
TIMING MARK DETECTOR

REFERENCES

Brochure of Humphrey Instruments Incorporated, 3081 Teagarden Street, San Leandro, California 94577

Ophthalmic Optics Lab Manual, by Michael P. Keating, 1978.