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Calculated Versus A-Scan Result for Axial Length Using Different Types of Ultrasound Probe Tip

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Summary
The axial lengths of 30 pseudophakic eyes were determined by calculation using geometric optics and by A Scan ultrasound using focused fluid filled 'soft' and solid probes.

The results from the same ultrasound machine using both types of probe were analysed for their correlation with the calculated axial lengths. The majority of the ultrasound results were shorter than their calculated values but those obtained with the fluid filled 'soft' probe (with consequently less corneal indentation and axial length shortening) were significantly more accurate than those from the solid probe ($0.02>p>0.01$).

Preoperative biometry prior to cataract surgery is becoming a routine in many hospitals. The most common measurements made are axial length (using ultrasound) and keratometry. Other parameters, such as lens implant constant and surgeon factors may be included in the final assessment to predict the required intraocular lens (IOL) power.

This study was designed to compare the accuracy of axial length measurements using two different designs of focused ultrasound probe on the same machine.

It has been argued that the solid probe system, although quick and easy to use, may compress the cornea and shorten the axial length reading. Although a slightly less convenient and more time consuming measurement, the fluid filled 'soft' probe has been introduced in an attempt to reduce this error.

A series of pseudophakic eyes were each scanned twice using the same machine, once with each type of probe. The results were analysed for their correlation with the calculated axial length.

Method

Thirty-four pseudophakic eyes from 20 patients were examined. Four eyes were excluded because the ultrasound measurements were not reproducible or satisfactory in accordance with the manufacturers' recommendations for use of the ultrasound machine.

Thirty eyes were therefore included in the study. All had a Rayner Haworth Equilimb IOL with capsular bag fixation and all had a best corrected visual acuity of 6/9 or better. This lens was chosen as it has previously been shown to be stable through a wide range of varying ciliary tone[1]. The following data were recorded for each eye:

(1) Best corrected visual acuity with subjective refraction to within 0.25D.
(2) Back vertex distance in mm.
(3) Keratometry using Javal Schiotz Keratometer.
(4) Corneal thickness using Haag Streit pachymeter.
(5) IOL depth using Haag Streit pachymeter.
(6) A Scan axial length using Storz Alpha II* Ultrasound with
    (a) Fluid filled Softip* focused probe (Fig. 1a)
    (b) Solid tip focused probe (Fig. 1b)

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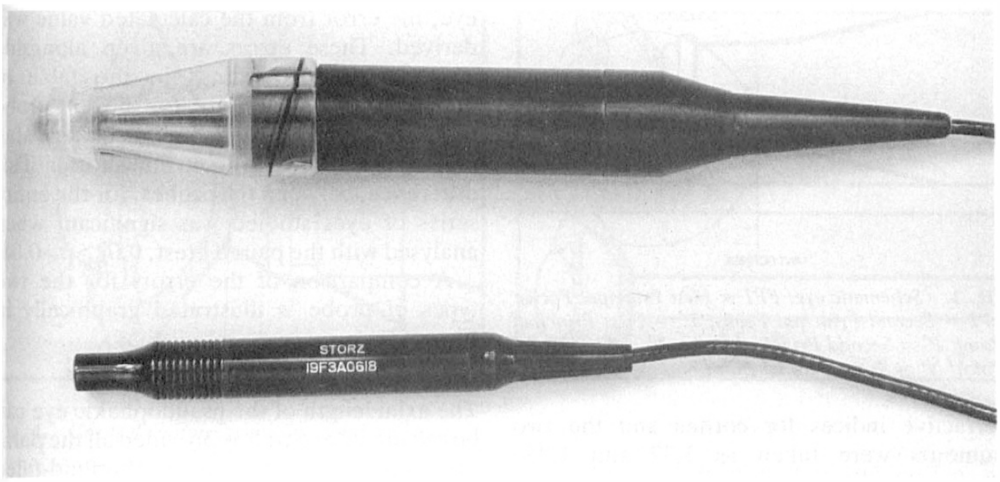

Fig. 1. *(Top) Focused fluid filled 'soft' probe. (Bottom) Focused solid probe.*

both using 'Dense cataract mode' with an assumed aggregate eye velocity of 1550 m/sec^2 in accordance with the manufacturers' recommendations for measuring the pseudophakic axial length. The relevant IOL Data were obtained from the manufacturer, and the

Table I *Table showing results and error scores when compared with calculated results*

Patient No.	*Calculated*	*Soft Probe*	*Solid Probe*	*Soft Error*	*Solid Error*	*Error Diff.*
1	23.000	21.940	21.660	1.06	1.340	−0.280
2	22.400	20.970	20.880	1.43	1.520	−0.090
3	23.560	23.530	23.430	0.03	0.130	−0.100
4	23.700	23.460	21.340	0.24	2.360	−2.120
5	25.390	24.040	24.080	1.35	1.310	0.040
6	24.350	24.210	24.010	0.14	0.340	−0.200
7	22.220	22.310	22.490	0.09	0.270	−0.180
8	23.920	23.240	22.420	0.68	1.500	−0.820
9	24.470	23.510	22.940	0.96	1.530	−0.570
10	23.870	23.260	22.520	0.61	1.350	−0.740
11	21.900	21.380	21.140	0.52	0.760	−0.240
12	22.140	21.400	20.760	0.74	1.380	−0.640
13	22.580	21.810	21.940	0.77	0.640	0.130
14	24.640	24.560	24.390	0.08	0.250	−0.170
15	23.550	23.520	23.120	0.03	0.430	−0.400
16	23.380	23.010	22.910	0.37	0.470	−0.100
17	23.510	22.740	23.110	0.77	0.400	0.370
18	26.670	26.400	26.280	0.27	0.390	−0.120
19	24.610	24.540	24.540	0.07	0.070	0.000
20	24.020	23.420	23.480	0.60	0.540	0.060
21	23.970	23.540	23.940	0.43	0.030	0.400
22	23.360	23.550	23.030	0.19	0.330	−0.140
23	24.810	24.770	24.750	0.04	0.060	−0.020
24	25.030	24.400	24.850	0.63	0.180	0.450
25	23.030	23.030	23.020	0.00	0.010	−0.010
26	24.080	24.030	23.070	0.05	1.010	−0.960
27	24.150	23.970	23.290	0.18	0.860	−0.680
28	27.640	27.300	27.570	0.34	0.070	0.270
29	22.130	21.700	21.600	0.43	0.530	−0.100
30	22.450	21.620	21.270	0.83	1.180	−0.350

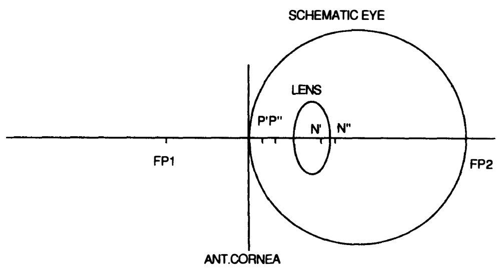

Fig. 2. *Schematic eye: FP1 = First Principal Focus; FP2 = Second Principal Focus; P' = First Principal Point; P" = Second Principal Point; N' = First Nodal Point; N" = Second Nodal Point.*

refractive indices for cornea and the two humours were taken as 1.37 and 1.336 respectively.[3]

Results

The results obtained are illustrated in Table I.

The calculated axial lengths were derived from the distance between the Second Principal Focus (FP2) and the corneal epithelium (Fig. 2). The position of FP2 was found by a method using geometric optics previously described.[4] The details of an example calculation are given in Appendix 1.

For each ultrasound measurement for each eye, the error from the calculated value was derived. These errors are given alongside their respective readings in the table of results. The average error for the soft probe was 0.44 mm shorter than the calculated value and for the solid probe 0.66 mm shorter. This difference, between the probes, for the entire series of eyes studied was significant when analysed with the paired t test, $0.02>p>0.01$.

A comparison of the errors for the two types of probe is illustrated graphically in Figure 3.

Discussion

The axial length of the pseudophakic eye can be calculated accurately provided all the parameters necessary are known. The fluid filled soft probe provided a significantly closer correlation than did the same machine using a solid probe.

The determination of the axial length of the eye and its relation to its refractive state *in vivo* has been a topic of interest for many years. Rushton[5] described a method of axial length determination based on the visibility of X-ray phosphenes in the dark adapted eye but the complexity of the instrumentation required limited its clinical applications.

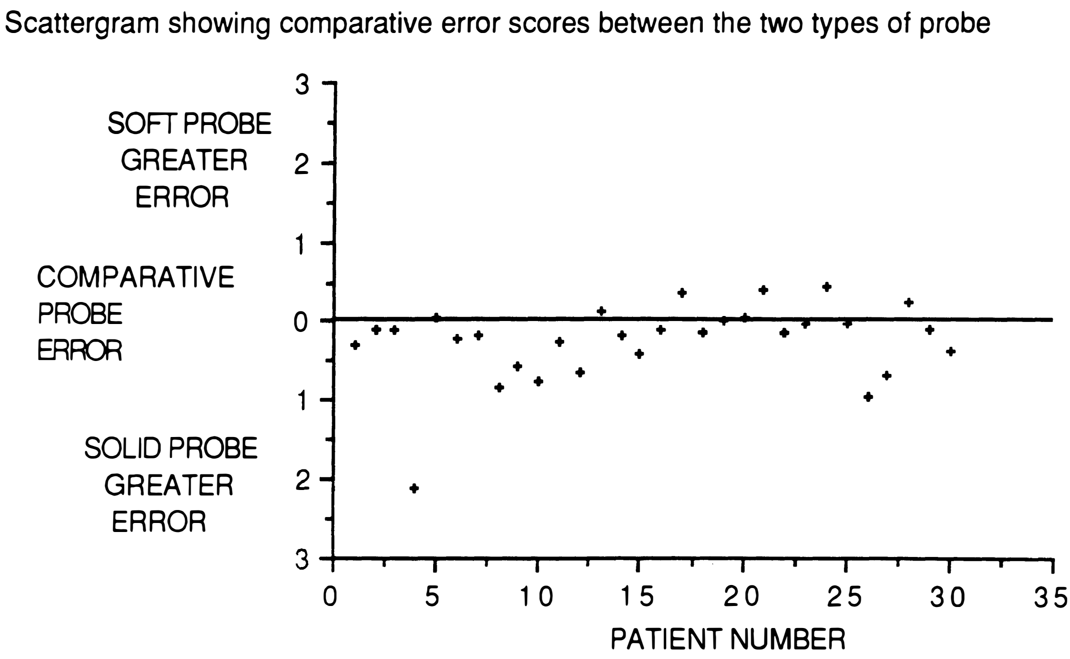

Fig. 3. *Graph showing relative probe errors.*

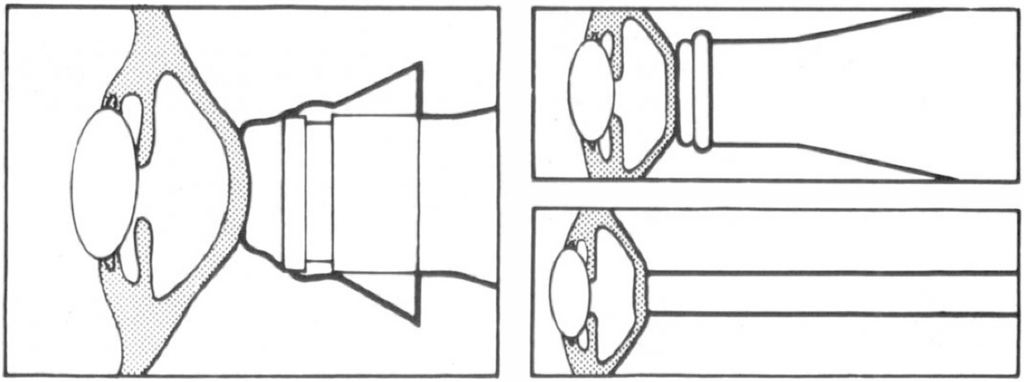

Fig. 4. *Corneal compression using solid probe.*

Ultrasound provides a quick and easy means of measuring axial length and various workers have assessed the accuracy of this means of measurement. Jansen[6] measured the anterior chamber depth using optical methods and compared this with the ultrasound result. Elenius,[7] in a small series of aphakic eyes, made an estimate of the refractive error based on the ultrasound axial length readings and was able to predict the spectacle correction required in all but one case to within 0.5D corresponding to an axial length of 0.35 mm. Other authors using aphakic eyes have assessed the accuracy of A scan using focused transducers with a stand off water bath[8] and non focused water bath transducer versus fluid filled soft probe.[9]

Comparisons between phakic, cataractous eyes have been made using noncontact immersion probes and contact probes.[10] The disadvantage of studying phakic eyes is that the crystalline lens dimensions and refractive index are unknown and accurate axial length determination by means other than ultrasound, for comparison, are difficult.

The aphakic eye provides an ideal situation to calculate the axial length, as all the refractive power is contained in the cornea. However, ultrasound measurements may be at a disadvantage as there are no lens echoes to guide the operator toward optimum A scan alignment.[8]

Ultrasound measurement of the axial length in the pseudophakic eye is complicated by the altered speed of ultrasound through PMMA. The velocity of ultrasound in aqueous and vitreous has been established as 1532 m/sec and in normal crystalline lens as 1640.5 m/sec.[11] The ultrasound velocity in cataractous lenses may be variable between 1590 and 1670 m/sec[12] and in PMMA has been measured as 2700 m/sec. In this study the A scan was operated on 'Dense cataract mode' as recommended for pseudophakic measurements. This operates using an assumed aggregate eye velocity of 1550 m/sec. The PMMA intraocular lens is highly echogenic and this mode of operation retains the anterior implant echo for alignment purposes but excludes the multiple echo formation obtained from the posterior surface of the implant. If a large number of measurements are taken for each eye in groups of 3 to 5 readings, any errors due to misalignment are apparent as a bimodal type of distribution to the results and may be excluded. As this study compares two different types of probe on the same ultrasound machine, both using the same aggregate ultrasound velocity, differences between the two sets of results will be determined by the probe type used.

The A Scan measurement of axial length is a measurement from the cornea to the vitreoretinal interface whereas the calculated result is a determination of the distance between cornea and photoreceptors and for any given eye will be a consequently longer value due to the included thickness of the retina. If a value for the retinal thickness, say, 0.2–0.4 mm[13] is added to the ultrasound error it can be seen that the Softip* probe shows a very close correlation indeed with the calculated value.

The recorded axial lengths using the solid probe were consistently shorter and this may be attributed to the greater corneal indentation caused during the measurement (Fig. 4). Although a slightly less convenient and more time consuming measurement to make, this study supports the claim for the superior accuracy of a fluid filled soft probe in the A Scan measurement of axial length.

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Appendix 1

Example Calculation

Data: Spectacle Lens: −1.00D
Av. K reading: 7.9 mm
IOL Depth: 4.55 mm
BVD 12 mm
Cornea Thickness: 0.5 mm

IOL Data: (21 Dioptre)
Ref. Index: 1.49
Ant. Radius Curvature 30.67 mm
Post. Radius Curvature 9.84 mm
Optic Thickness 0.7 mm

(1) *At Spectacle Lens*
1/v − 1/u = 1/f   u = infinity
therefore v = f = 1000/P, therefore v = −1000

(2) *At Anterior Cornea*
u = v-12 mm = −1012
n2/v − n1/u = n2−n1/r
therefore, 1.37/v − 1/−1012 = 1.37 − 1/7.9
therefore v = 29.88

(3) *At Posterior Cornea*
u = v − 0.5 mm = 29.38
n2/v − n1/u = n2 − n1/r
therefore, 1.336/v − 1.37/29.38 = 1.336 − 1.37/7.9
therefore, v = 31.56

(4) *At Anterior IOL*
u = v − 4.55 mm = 27.01 mm
n2/v − n1/u = n2−n1/r
therefore, 1.49/v − 1.336/27.01 = 1.49 − 1.336/30.67
therefore v = 27.34

(5) *At posterior IOL*
u = v −0.7 mm = 26.65
n2/v − n1/u = n2−n1/r
therefore, 1.336/v − 1.49/26.65 = 1.336 − 1.49/−9.84
therefore v = 18.67

(6) FP2 = 18.67 + optic thickness + IOL depth + cornea thickness
therefore FP2 = 18.67 + 0.7 + 4.55 + 0.5 = 24.42 mm