Refractive Shifts in Four Selected Artificial Vitreous Substitutes Based on Gullstrand-Emsley and Liou-Brennan Schematic Eyes

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PURPOSE. To determine and compare the refractive shifts based on Gullstrand-Emsley and Liou-Brennan schematic eyes after filling them with four selected artificial vitreous substitutes: silicone oil, heavy silicone oil, hydrogels, and encapsuled balanced salt solution.

METHODS. The optical constants of artificial vitreous body–filled eyes were calculated based on Gullstrand-Emsley and Liou-Brennan schematic eyes with accommodation relaxed. The theoretical refractive shifts in these two models were compared in pars plana vitrectomy (PPV), PPV plus lensectomized and PPV plus intraocular lens (IOL) eyes after four artificial vitreous tamponades.

RESULTS. The Gullstrand-Emsley schematic eye shows refractive shifts of +8.710, −4.544, +1.136, and −0.338 D in PPV eyes; +11.044, +20.332, +16.351, and +17.413 D in PPV plus lensectomized eyes; and the need for IOL powers of +22.195, +22.366, +22.292, and +22.312 D in PPV plus IOL eyes in silicone oil, heavy silicone oil, hydrogels, and encapsuled balanced salt solution tamponade eyes, respectively. Similarly, the Liou-Brennan schematic eye induced shifts of +6.260, −3.266, +0.817, and −0.272 D in PPV eyes; +13.181, +20.654, +17.451, and +18.305 D in PPV plus lensectomized eyes; and the need IOL powers of +13.522, +23.767, +19.389, and +20.558 D in PPV plus IOL eyes, respectively.

CONCLUSIONS. The Gullstrand-Emsley schematic eye is a convenient and accurate model for predicting refractive shifts for hydrogels and encapsuled balanced salt solution substitutes in PPV eyes. The Liou-Brennan schematic eye is recommended for silicone oil and heavy silicone oil in PPV eyes and for all four substitutes in PPV plus lensectomized eyes and PPV plus IOL eyes. In addition, the encapsuled balanced salt solution changes the refraction little in either schematic eye. (*Invest Ophthalmol Vis Sci.* 2009;50:3529–3534) DOI:10.1167/iovs.08-2802

Since the 1970s, pars plana vitrectomy (PPV) has been one of the most important ophthalmic surgeries for treating several blinding diseases by removing and replacing the diseased vitreous body.[1–3] Because the natural vitreous body is unable to regenerate, the vitreous cavity must be filled with suitable artificial materials, which can then keep the retina in place and prevent it from detaching again. Clinically, a number of artificial vitreous substitutes have been used, including silicone oil, heavy silicone oil, and polymeric gels.[4–11] However, these materials may lead to undesirable side effects and can induce severe complications, the most common of which is cataract formation in phakic eyes.[12] Therefore, it is necessary to perform PPV combined with lensectomy to remove the cataract and reserve the anterior lens capsule in some patients.[13] Recently, we devised a novel, foldable, artificial vitreous body consisting of a very thin (<30 μm thick) vitreous-like capsule with a silicone tube–valve system. This capsule can be folded and implanted into the vitreous cavity through a 1.5-mm incision in the sclera. Balanced salt solution (BSS; Alcon Ltd., Fort Worth, TX) was then injected into the capsule, which was filled to support the retina and to control intraocular pressure (IOP) through the tube–valve system, which is subsequently fixed under the conjunctiva.[14] Results from an animal study show that this novel artificial vitreous body device can effectively support the retina and control IOP and has good biocompatibility.[14] The main parameters of the encapsuled balanced salt solution vitreous body's patellar fossa are as follows: central depth, 2.00 mm; radius of curvature, −6.00 mm; and capsule's axial thickness, less than 30 μm. Because the axis is far thinner than the crystalline lens' first and second surfaces (0.546 and 0.635 mm, respectively[15]), the encapsuled balanced salt solution vitreous body's index is thought to equal water's ($n = 1.333$).

Because the artificial vitreous media's refractive indices (silicone oil, $n = 1.405$[16]; heavy silicone oil, $n = 1.300$[8]; cross-linked poly [1-vinyl-2-pyrrolidinone] hydrogel, $n = 1.345$[9]) differ from that of the natural vitreous body ($n = 1.336$), induced refractive shifts in tamponade eyes are expected. Therefore, to avoid undesired refractive changes, it is very important to calculate the theoretical postoperative refractive shifts after these artificial vitreous tamponades are used. To our knowledge, only one published paper describes how to calculate the theoretical postoperative refraction of +9.30 D in silicone oil–filled eyes.[16] However, little is known about the refractive shifts that occur with other artificial vitreous media.

Historically, numerous schematic eyes have been used to assess the optical refraction of the human eye, including the Lotmar,[17] Kooijman,[18] Gullstrand-Emsley,[15] Liou-Brennan,[19] Escudero-Navarro[20] and David Atchison[21] schematic eye models. Among these models, the Gullstrand-Emsley schematic eye is the classic, simplest, and most widely used model for most

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Supported by Grant 06104574 from the Science and Technology Foundation of Guang Dong Province of China, Grant 2006Z2-E0141 from the Science and Technology Foundation of Guang Zhou City of China, and Grant NCET-07-0876 from the New Century Excellent Talent Foundation.

Submitted for publication August 31, 2008; revised December 8, 2008, and February 20, 2009; accepted May 19, 2009.

Disclosure: **Q. Gao** , None; **X. Chen**, None; **J. Ge**, None; **Yo. Liu**, None; **Z. Jiang**, None; **Z. Lin**, None; **Ya. Liu**, None

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Investigative Ophthalmology & Visual Science, July 2009, Vol. 50, No. 7

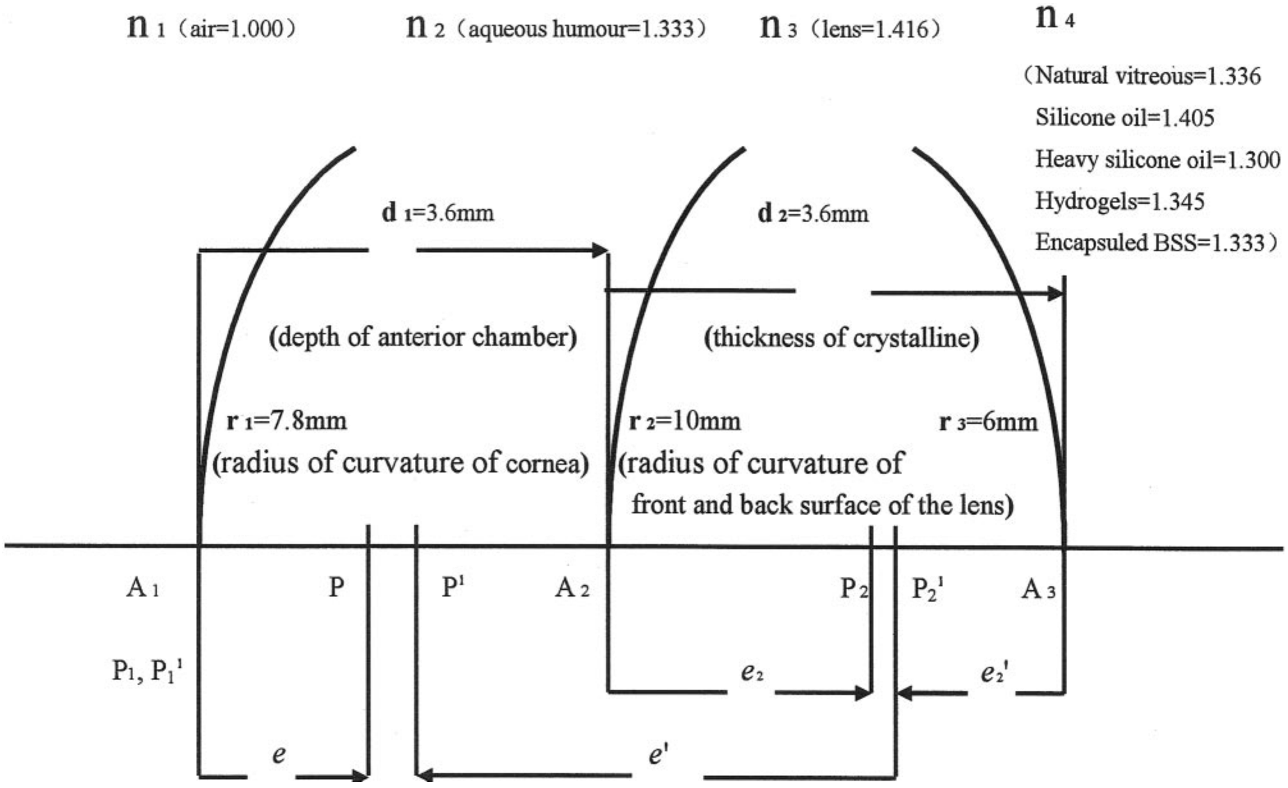

Figure 1. The optical constants of artificial vitreous body–filled eyes based on the Gullstrand-Emsley schematic eye.

ophthalmologists, for its spherical surfaces, reduced cornea and direct and easy formula calculation. On the other hand, both Liou-Brennan's and Atchison's models have been shown to match real eye data more closely than the Gullstrand-Emsley schematic eye.[22] In particular, Liou-Brennan's model adopts the empiric values of ocular parameters from healthy emmetropic eyes,[19] and comes closest to human eyes' anatomy. Therefore, this study's purpose was to determine and compare the refractive shifts based on the Gullstrand-Emsley and Liou-Brennan schematic eyes, using silicone oil, heavy silicone oil, hydrogels, and encapsuled balanced salt solution tamponades in PPV eyes, PPV plus lensectomized eyes and PPV plus intraocular lens (IOL) eyes.

METHODS

Refractive Calculations

Gullstrand-Emsley Schematic Eye. The optical constants of artificial vitreous-filled eyes were calculated based on schematic eyes with accommodation relaxed.[15] As shown in Figure 1, n_1, n_2, n_3, and

Table 1. Optical Calculations after Silicone Oil and Encapsulated Balanced Salt Solution Tamponades in PPV-Alone Eyes

Natural Vitreous	Silicone Oil	Encapsulated Balanced Salt Solution
The refractive power of cornea (F_C): $F_C = (n_2 - n_1)/r_1 = (1.333 - 1)/0.0078$ $= 42.735$ D	The refractive power of cornea (F_C): $F_C = (n_2 - n_1)/r_1 = (1.333 - 1)/0.0078$ $= 42.735$ D	The refractive power of cornea (F_C): $F_C = (n_2 - n_1)/r_1 = (1.333 - 1)/0.0078$ $= 42.735$ D
The refractive power of front surface of the lens (F_1): $F_1 = (n_3 - n_2)/r_2 = (1.416 - 1.333)/0.01 = 8.270$ D	The refractive power of front surface of the lens (F_1): $F_1 = (n_3 - n_2)/r_2 = (1.416 - 1.333)/0.01 = 8.270$ D	The refractive power of front surface of the lens (F_1): $F_1 = (n_3 - n_2)/r_2 = (1.416 - 1.333)/0.01 = 8.270$ D
The refractive power of back surface of the lens (F_2): $F_2 = (n_4 - n_3)/r_3 = (1.336 - 1.416)/-0.006$ $= 13.333$ D	The refractive power of back surface of the lens (F_2): $F_2 = (n_4 - n_3)/r_3 = (1.405 - 1.416)/-0.006$ $= 1.833$ D	The refractive power of back surface of the lens (F_2): $F_2 = (n_4 - n_3)/r_3 = (1.333 - 1.416)/-0.006$ $= 13.783$ D
The equivalent power of the lens (F_L): $F_L = F_1 + F_2 - d_2/n_3 \times F_1F_2$ $= 8.270 + 13.333{-}0.0036/1.4160 \times 8.270 \times 13.333$ $= 21.323$ D	The equivalent power of the lens (F_L): $F_L = F_1 + F_2 - d_2/n_3 \times F_1F_2$ $= 8.270 + 1.833 - 0.0036/1.4160 \times 8.270 \times 1.833$ $= 10.065$ D	The equivalent power of the lens (F_L): $F_L = F_1 + F_2 - d_2/n_3 \times F_1F_2$ $= 8.270 + 13.783 - 0.0036/1.4160 \times 8.270$ $\times 13.783$ $= 21.763$ D
The principal points of the lens: $e_2 = A_2P_2 = d_2n_2/n_3 \times F_2/F_L$ $= 0.0036 \times 1.333/1.4160 \times 13.333/21.323 \times 10^3$ $= 2.119$ mm	The principal points of the lens: $e_2 = A_2P_2 = d_2n_2/n_3 \times F_2/F_L$ $= 0.0036 \times 1.333/1.4160 \times 1.833/10.065 \times 10^3$ $= 0.617$ mm	The principal points of the lens: $e_2 = A_2P_2 = d_2n_2/n_3 \times F_2/F_L$ $= 0.0036 \times 1.333/1.4160 \times 13.783/21.763 \times 10^3$ $= 2.147$ mm
The equivalent power of the eye (F): $d = d_1 + e_2 = 3.600 + 2.119 = 5.719$ mm $F = F_C + F_L - d/n_2 \times F_CF_L$ $= 42.735 + 21.323 - 0.00572/1.333 \times 42.735$ $\times 21.323$ $= 60.148$ D	The equivalent power of the eye (F): $d = d_1 + e_2 = 3.600 + 0.617 = 4.217$ mm $F = F_C + F_L - d/n_2 \times F_CF_L$ $= 42.735 + 10.065 - 0.00422/1.333 \times 42.735$ $\times 10.065$ $= 51.438$ D	The equivalent power of the eye (F): $d = d_1 + e_2 = 3.600 + 2.147 = 5.747$ mm $F = F_C + F_L - d/n_2 \times F_CF_L$ $= 42.735 + 21.763 - 0.00575/1.333 \times 42.735$ $\times 21.763$ $= 60.486$ D

Table 2. Optical Calculations after Silicone Oil and Encapsulated Balanced Salt Solution Tamponades in PPV Plus Lensectomized Eyes

Natural Vitreous	Silicone Oil	Encapsulated Balanced Salt Solution
The refractive power of cornea (F_C): $F_C = (n_2 - n_1)/r_1 = (1.333 - 1)/0.0078 = 42.735$ D The refractive power of the lens (F_L): $F_L = F_1 = (n_3 - n_2)/r_2 = (1.336 - 1.333)/0.01 = 0.300$ D The equivalent power of the eye (F): $F = F_C + F_L - d/n_2 \times F_C F_L$ $= 42.735 + 0.300 - 0.0036/1.333 \times 42.735 \times 0.300 = 43.000$ D	The refractive power of cornea (F_C): $F_C = (n_2 - n_1)/r_1 = (1.333 - 1)/0.0078 = 42.735$ D The refractive power of the lens (F_L): $F_L = F_1 = (n_3 - n_2)/r_2 = (1.405 - 1.333)/0.01 = 7.200$ D The equivalent power of the eye (F): $F = F_C + F_L - d/n_2 \times F_C F_L$ $= 42.735 + 7.200 - 0.0036/1.3333 \times 42.735 \times 7.20 = 49.104$ D	The refractive power of cornea (F_C): $F_C = (n_2 - n_1)/r_1 = (1.333 - 1)/0.0078 = 42.735$ D The refractive power of the lens (F_L): $F_L = F_1 = (n_3 - n_2)/r_2 = (1.333 - 1.333)/0.01 = 0.000$ D The equivalent power of the eye (F): $F = F_C + F_L - d/n_2 \times F_C F_L$ $= F_C = 42.735$ D

n_4 represent air, aqueous humor, crystalline lens, and artificial vitreous, respectively. The refractive power of each spherical surface is calculated as $F = (n_2 - n_1)/r$, where n_1 and n_2 are the indices of refraction to the left and right of the surface, respectively, and r is the radius of the surface's curvature. The total compound power equals $F = F_C + F_L - d/n \times F_C F_L$, where F_C and F_L are the refractive power of the cornea and lens, respectively. The refractive indices, distances in the schematic eyes, and radius of the various surfaces' curvatures are also given in Figure 1. Among the four artificial vitreous substitutes selected, we give the calculation steps of refraction in silicone oil and the encapsuled balanced salt solution tamponade eyes in PPV eyes in Table 1 and the PPV plus lensectomized eyes in Table 2.

Liou-Brennan Schematic Eye. The refractive calculations were performed as previously described.[19,23] Briefly, the eye model was structured on a computer with optical design program software (ZEMAX EE Edition; ZEMAX Development Corp., Bellevue, WA). Then, the indices of the four selected artificial vitreous tamponades were changed accordingly, and the focus length and refractive power were calculated in PPV and PPV plus lensectomized eyes.

Lensectomy often includes removing the lens capsule during PPV surgery, but sometimes leaves the anterior capsule, which usually remains flat. Therefore, the refractive power after changes in the anterior lens capsule's curvature in silicone oil–filled eyes was also calculated, as shown in Table 3.

Calculation of the IOL Power Needed, Based on Two Schematic Eyes

To make the calculation of the needed IOL power easy to understand and master, we employed a commonly used foldable acrylic lens (AcrySofMA60BM; Alcon Ltd.). Its acrylic refractive index is 1.55 and its posterior radius of curvature is 16.0 mm.[24] Because the thickness of a +21-D IOL is 0.75 mm, we assumed the thickness was 0.75 mm. We then altered the anterior radius of curvature to arrive at the suitable IOL power. The calculations on the Gullstrand-Emsley schematic eye are shown in Table 4.

Table 3. Effect of Curvature of the Lens' Front Capsule on Refractive Power in PPV Plus Lensectomized Eye after Silicone Oil Tamponade

Radius of Curvature (mm)	Refractive Power (D)
5.400	53.527
6.400	51.765
7.400	50.480
8.400	49.500
9.400	48.729
10.400	48.106
11.400	47.592
12.400	47.162
13.400	46.795
14.400	46.480
15.400	46.205
16.400	45.964
17.400	45.751
18.400	45.560
19.400	45.390
20.400	45.236

On the Liou-Brennan schematic eye, we assume that the distance between the IOL's posterior surface and the remaining anterior surface of the crystalline lens, the central thickness, the posterior radius, and the index of IOL are 0, 0.75, 16, and 1.55 mm, respectively. With the index of four different artificial vitreous tamponades changing accordingly (ZEMAX; ZEMAX Development Corp.), the IOL's anterior surface was optimized to make the effective focal length of the PPV plus IOL eye 16.572 mm, which is the focal length of the Liou-Brennan eye model. Subsequently, with the optimized radius of the anterior surface, the posterior surface and the index of the IOL, and the IOL power for the PPV plus lensectomized eye with four different liquids, were calculated.

Results

Theoretical refraction, refractive shifts, and IOL power with natural vitreous and four selected substitutes in PPV eyes, PPV plus lensectomized eyes, and PPV plus IOL eyes based on two schematic eyes are shown in Tables 5, 6, and 7.

As Table 5 shows, we found that the theoretical refraction changed significantly only after silicone and heavy silicone tamponades, especially the silicone oil, based on two schematic eyes in PPV and PPV plus lensectomized eyes. For example, the theoretical refractions of the natural vitreous, silicone oil, heavy silicone oil, hydrogel, and encapsuled balanced salt solution were +60.148, +51.438, +64.692, +59.012, and +60.486 D, respectively, in the PPV eye, based on Gullstrand-Emsley schematic eye. Based on the Liou-Brennan schematic eye, although the refractive shifts of the four selected substitutes have some difference from the Gullstrand-Emsley schematic eye, the general tendency is the same, as the silicone oil greatly affects the tamponade eyes' refraction, and the encapsuled balanced salt solution comes closest to normal eyes' refraction.

Table 6 shows the refractive shifts from emmetropic eyes after four selected artificial vitreous tamponades and the deviation between the two schematic eyes. The silicone oil–filled eye induces the largest deviation, as much as −2.450 D in PPV and +2.137 D in PPV plus lensectomized eyes, the heavy silicone is second and the others have small deviations.

In Tables 5 and 6, we assumed that the curvature of the lens' front capsule was normal in the PPV plus lensectomized eyes. However, the curvature of the front capsule could be steeper or flatter and, as Table 3 shows, this greatly affected the refractive power in the silicone oil–filled eye based on the Liou-Brennan schematic eye.

Table 7 shows the IOL power needed in PPV plus lensectomized eyes with the four artificial vitreous tamponades and

Table 4. Needed IOL Power and Anterior Radius of Curvature on PPV Plus Lensectomized Eyes with Natural Vitreous and Silicone Oil Tamponades

	Natural Vitreous	Silicone Oil
Formula for F_L:		
$F = F_C + F_L - d/n_2 \times F_CF_L$ $d = d_1 + e_2$ $e_2 = d_2n_2/n_3 \times F_2/F_L$ $\Downarrow$	$60.148 - 42.735 + 0.00075 \times 42.735$ $\times (1.336 - 1.55)/1.55(-0.0016)$ $= (1 - 0.00645 \times 42.735/1.333)F_L$	$60.148 - 42.735 + 0.00075 \times 42.735$ $\times (1.405 - 1.55)/1.55(-0.0016)$ $= (1 - 0.00645 \times 42.735/1.333)F_L$
$F - F_C + d_2F_C \times (n_4 - n_3)/n_3r_3$ $= (1 - d_1F_C/n_2)F_L$	$17.413 + 0.277 = 0.793F_L$ $F_L = 22.307$ D	$17.413 + 0.187 = 0.793F_L$ $F_L = 22.195$ D
Formula for r_2:		
$F_L = F_1 + F_2 - d_2/n_3 \times F_1F_2$ $F_1 = (n_3 - n_2)/r_2$ $F_2 = (n_4 - n_3)/r_3$ $\Downarrow$ $F_L = (n_3 - n_2)/r_2 + (n_4 - n_3)/r_3$ $- \mathrm{d}_2/n_3 \times (n_3 - n_2)/r_2$ $\times (n_4 - n_3)/r_3$	$F_L = (1.55 - 1.333)/r_2 + (1.336 - 1.55)/(-0.016)$ $- 0.00075/1.55 \times (1.55 - 1.333)/r_2$ $\times (1.336 - 1.55)/-0.016$ $22.307 = 0.217/r_2 + 13.375 - 0.00140/r_2$ $r_2 = 24.2$ mm	$F_L = (1.55 - 1.333)/r_2 + (1.405 - 1.55)/(-0.016)$ $- 0.00075/1.55 \times (1.55 - 1.333)/r_2$ $\times (1.405 - 1.55)/(-0.016)$ $22.195 = 0.217/r_2 + 9.063 - 0.000952/r_2$ $r_2 = 16.4$ mm

the deviation between the two schematic eyes. The IOL power decreased when the artificial vitreous substitutes' refractive index increased. This tendency in the Gullstrand-Emsley model was tiny, fluctuating from +22.195 to +22.366 D; a range of +13.522 to +23.767 D was observed in the Liou-Brennan schematic eye. The encapsuled balanced salt solution caused approximately a −1.754 D deviation, and the correction on the silicone oil–filled eye was −8.673 D.

DISCUSSION

It is important for ophthalmologists to understand the optical principles behind the change in refractive power in different artificial vitreous body tamponades. The present study is the first report of the refractive shifts and postoperative IOL power after four selected artificial vitreous tamponades based on two schematic eyes and shows that silicone and heavy silicone profoundly affect refraction in PPV, PPV plus lensectomized eyes, and PPV plus IOL eyes.

The two schematic eyes used in this study were Gullstrand-Emsley and Liou-Brennan. The former is the simple and classic model of refractive calculations used by most ophthalmologists, and the latter is the most accurate and real model for human eyes, but needs special software and complex calculations. When these models were compared, there was no obvious difference between hydrogel- and encapsuled balanced salt solution–filled eyes, except that silicone oil induced the largest deviation, −2.450 D in PPV and +2.137 D in PPV plus lensectomized eyes. With good biocompatibility and few refractive changes, as both schematic eyes showed, the foldable artificial vitreous body seems most suitable and come closest to normal eyes after PPV surgery.

Our theoretical refractive shift (+8.710 D) based on the Gullstrand-Emsley schematic eye in silicone oil–filled eyes with PPV alone is very close to the previous results of +9.30 D demonstrated by Stefansson et al.,[16] which are carried on "backward" from the retina toward the cornea. The purpose of that method was to find a corneal contact lens that allows parallel light to focus on the retina for the patient's distance vision. In contrast, our calculation was performed using mathematical methods based on the Gullstrand-Emsley schematic eye with accommodation relaxed. In which the equivalent power of the cornea and the crystalline lens and their principal points were determined consecutively. Then the two systems were combined to determine the eye's equivalent power. However, these two theoretical values were more hyperopic than +6.260 D with the Liou-Brennan schematic eye, which has been shown to closely resemble actual postoperative refractions as reported by Smith et al. (+5.57 ± 4.01 D),[25] Pavlovic et al.[26] (+5.07 D), and Hotta et al.[5] (+5.69 ± 1.71 D) in PPV alone eyes. On the other hand, in the PPV plus lensectomized eye, the refractive shifts varied significantly.[25–27] Several factors could contribute to this difference, such as the amount of silicone oil filling,[28] curvature of the lens' front capsule (as shown in Table 3) and head position during retinoscopy.[29,30] Deviation in aphakic refraction is also associated with these factors regarding whether the patient's anterior lens capsule is left intact. When the lens capsule is absent, the power varies with the radius of curvature of the silicone oil's front surface. If the silicone oil at the pupil bulges through a small pupil, there can be a very steep curve at the oil's front surface, with high refractive power; but with no bulge and with a flat anterior surface, the refractive power will be low.

Table 5. Theoretical Refraction in Different Artificial Vitreous Body Tamponade Eyes Based on Two Schematic Eyes

Ophthalmic Surgeries/Models	Natural Vitreous	Silicone Oil	Heavy Silicone Oil	Hydrogels	Encapsulated Balanced Salt Solution
PPV alone					
Gullstrand-Emsley	60.148	51.438	64.692	59.012	60.486
Liou-Brennan	60.343	54.083	63.609	59.526	60.615
PPV plus lensectomy					
Gullstrand-Emsley	43.000	49.104	39.816	43.797	42.735
Liou-Brennan	42.215	47.162	39.689	42.892	42.038

Data are expressed in diopters.

TABLE 6. Refractive Shifts and Deviation in Different Artificial Vitreous Body Tamponade Eyes Based on Two Schematic Eyes

Ophthalmic Surgeries/Models	Silicone Oil	Heavy Silicone Oil	Hydrogels	Encapsulated Balanced Salt Solution
PPV alone				
Gullstrand-Emsley	+8.710	−4.544	+1.136	−0.338
Liou-Brennan	+6.260	−3.266	+0.817	−0.272
Deviation	−2.450	+1.278	−0.319	+0.066
PPV plus lensectomy				
Gullstrand-Emsley	+11.044	+20.332	+16.351	+17.413
Liou-Brennan	+13.181	+20.654	+17.451	+18.305
Deviation	+2.137	+0.322	+1.100	+0.892

Data are expressed in diopters.

TABLE 7. Needed IOL Power in PPV Plus Lensectomized Eyes with Four Selected Artificial Vitreous Tamponades

Models	Natural Vitreous	Silicone Oil	Heavy Silicone Oil	Hydrogels	Encapsulated Balanced Salt Solution
Gullstrand-Emsley	22.307	22.195	22.366	22.292	22.312
Liou-Brennan	20.266	13.522	23.767	19.389	20.558
Deviation	−2.041	−8.673	1.401	−2.903	−1.754

Data are expressed in diopters.

After PPV plus lensectomy with silicone oil tamponade, many patients need an IOL to improve their vision. Clinically, an inferometer (IOL Master; Carl Zeiss Meditec) is used to measure the axial length of silicone oil–filled eyes, and then the SRK-II formula is applied to determine the IOL's power; the usual power is +21.00 D after phacoemulsification with natural vitreous.[31]

For postoperative IOL power calculation, the Gullstrand-Emsley model may fail to predict refraction; the deviations in natural vitreous and silicone oil are −2.041 and −8.673 D, respectively. The IOL's thickness and posterior radius of curvature may significantly contribute to these deviations.[32] When the thickness is 0.75 and 3.6 mm, the IOL's power will be 22.307 and 21.176 D, respectively; so the Liou-Brennan model should be recommended. But most ophthalmologists have had no contact with this complex model before, so the deviations from the Gullstrand-Emsley model could be used to predict refractive results in the Liou-Brennan schematic eye.

The Gullstrand-Emsley schematic eye is a convenient and accurate model to predict refractive shifts for hydrogels and encapsuled balanced salt solution substitutes in PPV eyes. The Liou-Brennan schematic eye is recommended for silicone oil and heavy silicone oil in PPV eyes and for all four substitutes in PPV plus lensectomized eyes and PPV plus IOL eyes. In addition, encapsuled balanced salt solution changes the refraction little in either schematic eye.

Acknowledgments

The authors thank Aldo Martinez (Institute for Eye Research Limited and School of Optometry and Vision Science, University of New South Wales, Sydney, Australia) for revision and improvements in the grammar and structure of the manuscript.

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