PERSPECTIVES IN REFRACTION

MELVIN L. RUBIN, EDITOR

Elimination of Aniseikonia in Monocular Aphakia with a Contact Lens-Spectacle Combination

ROBERT J. SCHECHTER, M.D.

Department of Ophthalmology, Albany Medical College, Albany, New York

Abstract. Correction of monocular aphakia with contact lenses generally results in aniseikonia in the range of 7–9%; with correction by intraocular lenses, aniskeikonia is approximately 2%. We present a new method of correcting aniseikonia in monocular aphakics using a contact lens-spectacle combination. A formula is derived wherein the contact lens is deliberately overcorrected; this overcorrection is then neutralized by the appropriate spectacle lens, to be worn over the contact lens. Calculated results with this system over a wide range of possible situations consistently results in an aniseikonia of 0.1%. (**Surv Ophthalmol 23**:57–61, 1978)

Key words. aniseikonia • aphakia • contact lenses • optics • intraocular lenses • monocular aphakia • unilateral aphakia

It has been facetiously stated that one of the complications of cataract surgery is aphakia. This is particularly true in cases of unilateral cataract extraction. Spectacle correction of monocular aphakia has been variously reported to give image magnification of 22 to 35%[14] in the aphakic eye. This large discrepancy in image size is thought to preclude the possibility of binocular vision in spectacle correction of monocular aphakia (although some have reported a limited success even with this group[16]).

Contact lenses are far less visually disabling than aphakic spectacles. They eliminate the roving ring scotoma and so-called "jack-in-the-box" phenomenon, and provide full peripheral vision. They reduce the image magnification of the corrected aphakic eye to approximately 7 to 12%.[5,15,18]

The use of the intraocular lens has gained popularity recently with those who feel it provides a more satisfactory correction of the optical problems of aphakia. Because of its more posterior position in the eye, it provides somewhat less image magnification than contact lenses or spectacles in aphakia.[19]

The normal tolerance for aniseikonia has been measured as between 5 and 8% by different methods.[8] Lubkin and Linksz[16] have reported achieving binocular vision with an aniseikonia of up to 26%, but do not define or analyze what they mean by the term "binocular vision." It seems reasonable that the quality of useful binocular vision possible in monocular aphakia should be related to the degree with which aniseikonia can be

minimized. Indeed, a significant correlation has been found between increasing aniseikonia and decreasing stereopsis.[13] No stereopsis was demonstrable with an aniseikonia of greater than 19%, and the stereopsis quantitatively increased as the aniseikonia was decreased. The ability to fuse images when there is a considerable difference in size ultimately depends upon the width of Panum's area.[6] It has been said that if this sensory fusion width falls below physiological values, lesser degrees of aniseikonia may also induce a disturbing effect, possibly even an aniseikonia of 2% or less.[8]

A clinical study[12] compared 30 monocularly aphakic patients corrected with contact lenses with another 30 patients who had received intraocular lens implants. The average visual acuity of both groups was comparable, with the intraocular lens patients wearing supplementary spectacle correction. The average stereopsis of the two groups was 46% and 82%, respectively; this is probably related to the average aniseikonia (measured to the nearest 0.25%) of 6.99% in the former group and 1.92% in the latter.

The results in children are even more dramatic. A child who finds it difficult to fuse the images of both eyes can escape the problem with suppression and amblyopia.[3,4] Results of contact lens correction of monocular aphakia in children have been disappointing, with a high incidence of amblyopia and heterotropia.[2-4,9,21] Orthoptic and visual results following intraocular lens implantation are said to be superior[1-4,21] at least partially because of the decreased image magnification and aniseikonia in such patients. (Jaffe, however, has indicated that he does not believe that it is safe or desirable to use lens implants in children.[14])

It is clear that the minimization of aniseikonia is a goal to be actively sought in optical correction of monocular aphakia. The problem is made somewhat more complicated by consideration of the fellow eye. It is not at all unusual for the phakic eye to be ametropic. Thus, the perceived retinal image size in that eye will be affected by the minification or magnification induced by the correcting spectacle lens.

The intraocular lens induces less image magnification than would a comparable contact lens. However, the absolute image magnification is not the key consideration. In monocular aphakia, the object is not to minimize the image magnification in the aphakic eye, but rather to provide the same degree of image size distortion as is provided by the optical correction of the phakic eye. The object is to minimize aniseikonia, not to minimize image magnification or minification. The major optical advantage of intraocular lenses has been said to be the decreased image magnification and aniseikonia that results from their use. It is clear that to obtain the highest quality, most useful binocular vision, aniseikonia must be minimized. These considerations lead ophthalmologists who recommend intraocular lenses into strategic dilemmas. In selecting the power of an intraocular lens to be used in correcting a monocular aphake with a high ametropia in his unoperated eye, which factors are to be weighed most strongly? The same intraocular lens that will minimize aniseikonia in such a patient will not permit clear distance vision without additional optical correction. In a patient with a myopic phakic eye, for example, the intraocular lens must be chosen in such a way as to make the pseudophakic myopic as well. (It is assumed, of course, that the patient continues with spectacle correction of the phakic eye. If a contact lens is tolerated in the unoperated eye, he would expect it to be tolerated in the operated eye as well, and many ophthalmologists would question the use of an intraocular lens in such a patient.)

A further difficulty arises when, at some time in the future, the second eye is ready for cataract surgery and possible intraocular lens implantation. The second lens must be chosen to optically match that in the first eye and the result will be a bilaterally pseudophakic patient who continues to require significant additional spectacle correction for both distant and near vision. Alternatively, the second intraocular lens may be chosen to make the eye emmetropic and dispense with the need for additional spectacle correction; such a choice, however, will result in a marked aniseikonia and binocular vision will be compromised. Finally, a third alternative requires a second operation on the original eye, to replace the first intraocular lens with another to achieve the goal of bilateral emmetropia. The repeated manipulation of the eye is undoubtedly detrimental, both cosmetically and functionally, and most ophthalmologists would prefer to avoid these repeated ocular insults if possible.

The advantage of contact lens correction, of course, is the ease and safety with which the contact lens can be repeatedly changed or modified without injury or damage to the ocular structures.

Contact lenses induce less change in image size change than do the corresponding spectacle lenses. It is possible to overcorrect an aphakic contact lens strength, so that a diverging lens will be necessary in the spectacle correction to provide clear distance vision. If the magnification of the spectacle lens is exactly neutralized by the minification of the spectacle lens, image magnification theoretically can be completely eliminated. The magnification or minification can be adjusted so as to cause a net image size change equal to that of the spectacle corrected phakic eye; thus aniseikonia can be minimized or eliminated. Such systems have been previously proposed, but each has had its limitations. Some have required individual eikonometric measurements in each case,[7] or ultrasonic determinations of the axial length of the eye.[22] It has also been suggested that a constant 7 to 9% pre-existing aniseikonia between the phakic and aphakic eye be assumed.[10,11] With a number of simplifying assumptions, we present a method of calculating such an aniseikonic galillean telescope system. It is necessary to know only the refractive error of each eye and the spectacle vertex distance, requirements which put this technique within the personal capabilities of any interested practitioner.

The technique utilizes the following simplifying assumptions.

1. The spectacle lenses are considered to be thin lenses; thus any image magnification due to thickness of the lens (the "shape factor"[17]) has been neglected. (The optician may be asked to match base curves and thickness in the two spectacle lenses, so that no added size error is introduced in the correction.[10])

2. We assume a negligible previous axial anisometropia. Thus, the formula considers only optical ametropia, and neglects specific mathematical consideration of any axial ametropia which may be present.

The angular image magnification of a refractive lens has been shown to be equal to $\frac{1}{1-pd}$,[20] where p is the power of the lens and d the distance from the eye in meters. The site of the 'entrance pupil' should be used in such analyses, nodal point construction being theoretically incorrect in cases of the blurred imagery of the uncorrected eye.[17] The corrected entrance pupil site may be taken as approximately 3 mm behind the cornea.[17]

Consider a contact lens of power P_c correcting the aphakic eye of a previously isometropic monocular aphakic patient. The contact lens, on the cornea, is 3 mm or 0.003 meters from the entrance pupil. Thus, the image magnification induced by the contact lens *(contact magnification)* is:

$$\frac{1}{1 - P_c(.003)}$$

The aphakic contact lens is then overplussed an amount P_o. Thus, the induced image magnification *(overplussed magnification)* is:

$$\frac{1}{1 - (P_c + P_o)(.003)}$$

It is then necessary to correct for the overcorrection P_o by the appropriate spectacle lens at vertex distance d from the cornea. Changing the position of a correcting refractive lens necessarily changes its dioptric power. It is known that a lens of power P will require a modified power of $\frac{P}{1+pd}$ if moved a distance d meters away from the cornea.[20] A lens of power $(-P_o)$ would be necessary to neutralize the overplussing at the corneal plane. This $(-P_o)$ is equivalent to a dioptric power of $\frac{-P_o}{1-P_od}$ at the spectacle plane. Thus, the magnification induced by the spectacle lens *(spectacle magnification)* is:

$$\frac{1}{1 + \frac{P_o}{(1 - P_od)}(d + .003)} = \frac{1 - P_od}{1 + P_o(.003)}$$

The *final magnification* induced by the contact lens-spectacle combination is therefore:

$$\left(\frac{(1)}{[1 - P_o + P_c)(.003)]}\right)\left(\frac{(1 - P_od)}{[1 + P_o(.003)]}\right)$$

It is desirable to have this final magnification equal approximately the image size magnification of the spectacle-corrected phakic eye. For instance, the dioptric power of the spectacle is S, worn at a vertex distance e meters from the cornea; the magnification induced by this spectacle lens worn over the unoperated eye *(phakic eye magnification)* is:

$$\frac{1}{1 - S(e + .003)}$$

and this is the magnification that the contact lens-spectacle combination should equal:

Power of Phakic Spectacle	Spectacle Vertex Distance	Power of Correcting Aphakic Contact Lens	Calculated Amount By Which Contact Is Over-Plussed	Final Power of Contact Lens (Sum of 2 Preceding Columns)	Power of Aphakic Spectacle Correction Made Necessary by Over-Plussed Contact	Image Magnification of Phakic Spectacle Lens	Image Magnification of Over-Plussed Contact Lens	Image Magnification of Aphakic Spectacle Lens	Net Image Magnification In Aphakic Eye (Product of 2 Preceding Columns)	Aniseikonia
- 15,00	12mm	- 1,00	+ 15,12	+ 14,12	- 18,50	0,8163	1,044	0,7828	0,8174	0,1%
- 12,00	12mm	+ 2,00	+ 13,12	+ 15,12	- 15,62	0,8475	1,048	0,8102	0,8487	0,1%
- 10,00	12mm	+ 5,00	+ 12,00	+ 17,00	- 14,00	0,8696	1,054	0,8265	0,8709	0,1%
- 10,00	12mm	+ 2,00	+ 11,37	+ 13,37	- 13,12	0,8696	1,041	0,8356	0,8705	0,1%
- 10,00	14mm	+ 2,00	+ 10,75	+ 12,75	- 12,62	0,8547	1,040	0,8234	0,8561	0,2%
- 8,00	12mm	+ 8,00	+ 10,75	+ 18,75	- 12,37	0,8929	1,060	0,8435	0,8938	0,1%
- 6,00	12mm	+ 8,00	+ 8,75	+ 16,75	- 9,75	0,9174	1,053	0,8724	0,9186	0,1%
- 3,00	12mm	+ 8,00	+ 5,50	+ 13,50	- 5,87	0,9569	1,042	0,9191	0,9579	0,1%
- 3,00	12mm	+12,00	+ 6,50	+ 18,50	- 7,00	0,9569	1,059	0,9050	0,9582	0,1%
- 3,00	14mm	+12,00	+ 5,87	+ 17,87	- 6,37	0,9515	1,057	0,9023	0,9534	0,2%
- 1,00	12mm	+10,00	+ 3,75	+ 13,75	- 3,87	0,9852	1,043	0,9451	0,9858	0,1%
- 0,50	12mm	+12,00	+ 3,62	+ 15,62	- 3,75	0,9926	1,049	0,9467	0,9933	0,1%
Plano	12mm	+12,00	+ 3,00	+ 15,00	- 3,12	1,0000	1,047	0,9553	1,000	0,0%
+ 0,50	12mm	+12,00	+ 2,37	+ 14,37	- 2,37	1,008	1,045	0,9657	1,009	0,2%
+ 2,00	12mm	+16,00	+ 1,50	+ 17,50	- 1,50	1,031	1,054	0,9780	1,032	0,1%
+ 2,00	14mm	+16,00	+ 1,00	+ 17,00	- 1,00	1,035	1,054	0,9833	1,036	0,1%
+ 3,00	12mm	+15,00	0	+ 15,00	Plano	1,047	1,047	1,000	1,047	0,0%
+ 5,00	12mm	+17,00	- 2,12	+ 14,87	+ 2,12	1,081	1,047	1,033	1,081	0,0%
+ 7,50	12mm	+20,00	- 4,87	+ 15,12	+ 4,62	1,127	1,048	1,075	1,126	0,1%
+10,00	12mm	+22,00	- 8,25	+ 13,75	+ 7,50	1,177	1,043	1,127	1,175	0,1%
+10,00	14mm	+22,00	- 9,00	+ 13,00	+ 8,00	1,205	1,041	1,157	1,204	0,0%

FIG. 1. Various values for the phakic and aphakic correction are considered, spanning most of the physiologic range. Calculated values for aphakic contact lens overcorrection are evaluated, and consistently yield a net aniseikonia of approximately 0.1%.

$$\left(\frac{1}{1-(P_o+P_c)(.003)}\right)\left(\frac{1-P_od}{1+P_o(.003)}\right) = \frac{1}{1-S(e+.003)}$$

$$1 - Se - S(.003) - P_od + P_odSe + P_odS(.003) = 1 + P_o(.003) - P_o(.003) - P_o^2(.000009) - P_c(.003) - P_cP_o(.000009).$$

Thus,

$$P_o[P_o(.000009) + P_c(.000009) - d + dSe + dS(.003)] = Se + S(.003) - P_c(.003)$$

It may be assumed that the first two terms in the above equation are sufficiently small that they may be disregarded without introducing significant error. Then,

$$P_o(Sde + Sd(.003) - d) = Se + S(.003) - P_c(.003)$$

Thus, P_o, the amount by which the aphakic contact lens should be overcorrected, is determined by

$$P_o = \frac{Se + S(.003) - P_c(.003)}{Sde + Sd(.003) - d}$$

For the usual case in which the phakic eye is corrected by a spectacle lens, d = e, and *(equation 1)*

$$P_o = \frac{Sd + S(.003) - P_c(.003)}{Sd^2 + Sd(.003) - d}$$

In the event that the phakic eye is approximately emmetropic, S = 0, and

$$P_o = \frac{P_c(.003)}{d}$$

In the latter case, since the vertex distance usually is between 12 and 15 mm., it is necessary only to overplus the aphakic contact lens by 20 to 25%.

Finally, in the unlikely event that the patient desires contact lens correction of the phakic eye (and thus presumably will wear a plano spectacle lens over that eye), e = o in the formula and

$$P_o = \frac{S(.003) - P_c(.003)}{Sd(.003) - d}$$

Using equation 1, hypothetical contact lens-spectacle combinations were calculated for eyes with various degrees of myopia and hyperopia (Fig. 1). It can be seen that, using this formula, the final calculated aniseikonia is approximately 0.1%. This is at least two orders of magnitude within the range that can be tolerated and permit good binocular vision and stereopsis. This means that even if the final aniseikonia in practice turns out to be somewhat higher, due perhaps to the simplifying assumptions, it may still be sufficiently small to make this technique clinically useful. A study of aniseikonia in monocularly aphakic patients with intraocular lens implants revealed an average aniseikonia of 1.92%,[12] with many patients testing at values larger than that; this is some 20 times greater than our calculated aniseikonia.

This method also provides superior cosmesis, particularly for the high myope or hyperope, in that the spectacle lens over the aphakic eye will be less dissimilar to the phakic correcting lens. Thus, the spectacle lenses will be more symmetrical and balanced in appearance. When the second eye is finally ready for cataract extraction, the first contact lens can easily be changed to make the patient bilaterally emmetropic while maintaining minimal aniseikonia. It has been pointed out that contact lenses are cosmetically less disfiguring than are intraocular lenses.[12]

Reduced aniseikonia is among the arguments which have been advanced by proponents of intraocular lenses. One group who investigated the problem in depth concluded that ". . . it may be difficult or impossible to reduce or eliminate the substantial amount of aniseikonia (9%) that remains after a unilateral aphakia is corrected by contact lenses."[18] Nevertheless, it is clear that, by using the simple formula derived herein, aniseikonia theoretically can be reduced or eliminated with a contact lens-spectacle combination, with results at least one order of magnitude superior to some intraocular lens series. As continuous wear soft and hard contact lenses become more widely available, it is hoped that this technique may prove applicable to an increasing number of clinical situations.

References

1. Bierlaagh JJM, vanderWee A, Kats A, et al: Techniques and perspectives of lens implants (pseudophakoi) in children. **Proc Second Internat Orthoptics Congr, Amsterdam (Int. Cong. Series No. 245)** Amsterdam, Excerpta Medica Foundation, 1971
2. Binkhorst CD, Gobin MH: Injuries to the eye with lens opacities in young children. **Ophthalmologica 148**:169–183, 1964
3. Binkhorst CD, Gobin MH: Pseudophakia after lens injury in children. **Ophthalmologica 154**:81–87, 1967
4. Binkhorst CD, Gobin MH, Leonard PAM: Post-traumatic artificial lens implants (pseudophakoi) in children. **Br J Ophthalmol 53**:518–529, 1969
5. Binkhorst CD: The optical design of intraocular lens implants. **Ophthal Surg 6**:17–31, 1975
6. Burian HM: Optics: Fusion in unilateral aphakia. **Trans Am Acad Ophthalmol Otolaryngol 66**:285–289, 1962
7. Christman EH: Correction of aniseikonia in monocular aphakia. **Arch Ophthalmol 85**:148–149, 1971
8. Crone RA, Leuridan OMA: Unilateral aphakia and tolerance of aniseikonia. **Ophthalmologica 171**:258–263, 1975
9. Daniel R: An evaluation of contact lenses in unilateral post-traumatic aphakic children. **Contact Lens 4**:19–24, 1974
10. Enoch JM: Use of inverted telescopic corrections incorporating soft contact lenses in the (partial) correction of aniseikonia in cases of unilateral aphakia. **Adv Ophthalmol 32**:54–66, 1976
11. Enoch JM: A spectacle-contact lens combination used as a reverse galillean telescope in unilateral aphakia. **Am J Optom 45**:231–240, 1968
12. Girard LJ, Friedman B, Moore CD, et al: Intraocular implants and contact lenses. A comparison of the visual functions of monocularly aphakic patients treated by pupillary intraocular lens implants and corneal contact lenses. **Arch Ophthalmol 68**:762–765, 1962
13. Highman VN: Stereopsis and aniseikonia in uniocular aphakia. **Br J Ophthalmol 61**:30–33, 1977
14. Jaffe NS: **Cataract Surgery and Its Complications.** St. Louis, CV Mosby, 1976, ed 2, pp 113, 123
15. Linksz A: Optical complications of aphakia, in Theodore FH (ed): **Complications after Cataract Surgery.** Boston, Little Brown, 1964, pp 597–634
16. Lubkin V, Linksz A: A ten-year study of binocular fusion with spectacles in monocular aphakia. **Am J Ophthalmol 84**:700–707, 1977
17. Ogle KN: **Optics.** Springfield, Charles C Thomas, 1968, ed 2, pp 138, 192, 204
18. Ogle KN, Burian HM, Bannon RE: On the correction of unilateral aphakia with contact lenses. **Arch Ophthalmol 59**:639–652, 1958
19. Schechter RJ: The optics of intraocular lenses, in Duane TD (ed): **Clinical Ophthalmology.** New York, Harper and Row, ed 2, (in press)
20. Schechter RJ: Image magnification, contact lenses, and visual acuity. **Ann Ophthalmol** (in press)
21. vanBalen AThM: Binkhorst's method of implantation of pseudophakia in unilateral traumatic cataract. **Ophthalmologica 165**: 490–494, 1972
22. van der Heijke GL: The optical correction of unilateral aphakia. **Trans Am Acad Ophthalmol Otolaryngol 81**:OP80–OP88, 1976

This project was supported in part by the National Institutes of Health Training Grant EY 07037.

Reprint requests should be addressed to Robert J. Schechter, M.D., Department of Ophthalmology, Southern California Permante Medical Group, 4900 Sunset Blvd., Los Angeles, California 90027.