Piggyback intraocular lens implantation

Robert E. Fenzl, MD, J. Pitzer Gills III, MD, and James P. Gills, MD

The piggyback method of implanting two intraocular lenses in one eye has been successfully expanded to address pseudophakic refractive error in normal eyes and eyes that have undergone postpenetrating keratoplasty. Piggyback implantation has been combined with the use of newly available minus-power lenses to provide appropriate power for a cataract patient with keratoconus, as well as to correct pseudophakic myopia. The phenomenon of increased depth of focus in piggybacks may be explained by a contact zone between the lenses. The late complication of interlenticular cellular growth with resultant hyperopic shift, opacification, and loss of vision has recently become a concern. Curr Opin Ophthalmol 2000, 11:73–76 © 2000 Lippincott Williams & Wilkins, Inc.

St. Luke's Cataract and Laser Institute, Tarpon Springs, Florida, USA

Correspondence to R.E. Fenzl, St. Luke's Cataract and Laser Institute, 43309 US Highway 19 N, Tarpon Springs, FL 34683, USA

Current Opinion in Ophthalmology 2000, 11:73–76

Abbreviations

DOF depth of focus
IOL intraocular lens
PK penetrating keratoplasty

ISSN 1040–8738

In 1993, Gayton [1] first described a unique solution to the problem of providing adequate intraocular lens (IOL) power to a patient with microphthalmos and extreme hyperopia—two IOLs implanted back to back. Since then, many surgeons have taken up the technique to less extreme cases of hyperopia in which a single high-power IOL would not have provided sufficient power and even to cases in which the required power was at or near the upper limit of power inventories [2] (Fig. 1). Implanting two IOLs in these cases is preferable, because when the optical centers of the lenses are aligned, they provide better optical quality than a single high-powered IOL. The procedure has been used not only to treat high hyperopia but also as a secondary technique to treat pseudophakic refractive errors to avoid the risks associated with lens exchange [3•]. With the advent of minus-power IOLs, the technique can benefit even myopic pseudophakes [3•,4]. Secondary piggyback implantation is helpful for patients who have had a corneal refractive procedure and are thus more likely to have postcataract surgery refractive error. Secondary piggybacks also can be used to correct the often high refractive errors of pseudophakic penetrating keratoplasty (PK) patients, for whom lens exchange presents even more risk [3•,5].

Power calculation for piggybacks

The short eyes that require piggyback implantation present challenges for power calculation. Optimizing axial length measurements does not guarantee the desired outcome. In a study by Holladay *et al.* [6], several hyperopic patients were examined, and detailed anatomic measurements were taken. In most cases, the short eyes had normal anterior segment dimensions (*ie,* corneal diameter, keratometry, and anterior segment length). The "abnormality" was a foreshortened axial length caused by a shortened posterior segment. Thus, most formulas underestimate the required power in these short eyes because they assume proportional anatomy. Also, placing two lenses in the bag changes the position of the posterior-most lens and thus changes its effective power [7].

A new Holladay power formula, the Holladay II, has been developed using additional measurements, for example, white-to-white corneal diameter and lens thickness, and takes into account the lens power shift caused by piggyback implantation.

The authors conducted a study [8•] to determine whether the new Holladay formula improved results for primary piggyback cases over the Loyd-Gills formula used with their empiric modifiers for piggyback calculation [9]. The authors found that both methods showed good predictability for most short eyes, with 90% of both groups within 1 D of the predicted refraction, but the Holladay II formula produced fewer outliers and was easier to use because it required no "fudge-factor" modifiers.

Secondary piggyback applications

High pseudophakic errors, if corrected at all, have traditionally been addressed by lens exchange, but lens exchange presents significant risk in pseudophakic eyes in which the lens has already fibrosed in place. Adding a second low-power implant as a secondary piggyback can safely and effectively address the refractive error (Fig. 2).

The power of a secondary piggybacked implant is also more predictable than an IOL exchange because (1) surgeons cannot be 100% sure of the power of the original IOL, (2) surgeons cannot be 100% confident that an exchanged IOL would be in the same plane as the old IOL, and (3) the power of the secondary implant is calculated purely by patients' refraction.

Gayton *et al.* [3•] reported the results of a series of secondary piggybacks, including a subset of postpenetrating keratoplasty patients. Fifteen patients were studied, including seven post-PK patients. Preoperatively, the cohort had a mean absolute deviation from emmetropia of 3.38 D (± 1.62 D), and postoperatively, they had a mean absolute deviation from emmetropia of 1.21 D (±0.90). Uncorrected visual acuity was improved in the cohort. Preoperatively, 7% (1) of the cases had uncorrected visual acuity 20/40 or better, whereas 64% (9) were 20/100 or worse. Postoperatively, 50% (7) were 20/40 or better uncorrected, and only 21% (3) were 20/100 or worse.

Minus-power piggyback lenses

The development of a regularly inventoried minus-power IOL (AMO DuraLens model PS-60AZB) has made practical secondary piggybacks for correcting significant pseudophakic myopic errors. The authors studied a cohort of patients receiving a secondary minus-power piggyback lens [4].

In 51 myopic pseudophakes, mean residual myopia of −3.05 D was reduced to −0.38 D. All cases were within 1 D of the desired refraction. 72% of eyes could see 20/40 or better, uncorrected, and best-corrected vision was 20/40 or better in 96% of cases. Uncorrected visual acuity was improved by two or more lines in 85% of cases and by five or more lines in 65% of cases. These results are especially impressive considering that these IOLs are only available in 1-D steps.

Minus-power piggyback in keratoconus

Primary minus-power piggyback implantation is rare, but a cataract patient with keratoconus presented with severe myopia requiring −14 D of power [10•]. Two negative-power IOLs were implanted to optimize visual results. Postoperative refraction at 1 day of +1.50 sphere necessitated an exchange of the anterior IOL. Fifteen weeks after the exchange, uncorrected visual acuity was 20/80 at distance and 20/50 at near. Best-corrected distance vision was 20/40 with −0.75 sphere.

A secondary issue in this case was the presence of a staphyloma, which complicated the ultrasound measurements. Staphylomas are common in extremely high myopes. In this case, a B-scan was used to more accurately calculate the axial length. Nevertheless, the patient still required a lens exchange, which resulted in a satisfactory outcome.

Image quality

At high dioptric powers (> ≈ 40 D), the image quality of piggyback lens systems is superior to that of a single lens. At such high powers, a single lens requires steep radii, producing significant spherical aberrations. The modulation transfer function would be decreased. Thus resolution is compromised, with a severely distorted image quality [6,11].

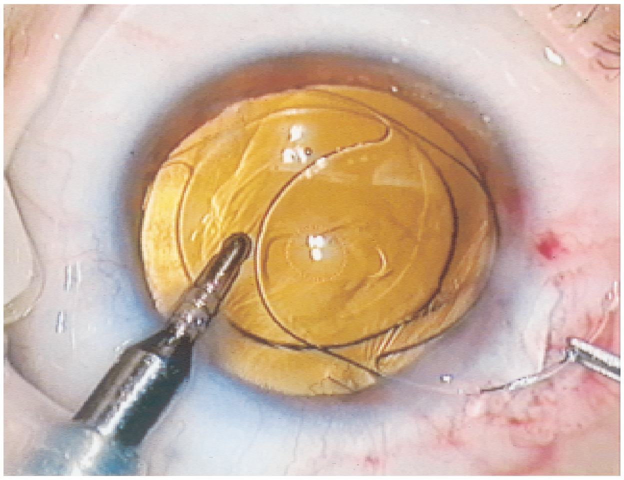
Hull *et al.* [12] have studied various lens shapes for extremely short eyes, which would minimize spheric aberration. They concluded that piggyback lens systems using lenses in currently available lens shapes provide excellent image quality. The optimum shape for maximizing axial image quality was found to be a piggyback system using two convex-plano lenses with the convex surfaces facing the cornea.

Increased depth of focus in piggyback eyes

The authors have clinically noted increased depth of focus (DOF) in many eyes receiving multiple implants. In a study comparing single-IOL cases with multiple-IOL cases, the authors performed defocus testing [2]. This procedure involves neutralizing the spherocylindric refractive error with trial frames, adding plus and minus sphere in 0.25-D increments from +6 to −6 and measuring Snellen acuity at each step. The region between 0 D and −3 D of defocus is of interest with respect to patients' distance, intermediate, and near vision. In a typical defocus pattern, the best distance vision occurs at 0 D defocus. Overminusing 1 D or 2 D measures intermediate-range vision. An overminus by as much as 2.5 D to 3.5 D provides the near-vision zone. The cut-off of functional uncorrected vision is 20/40. A typical monofocal IOL has a range of approximately 1.25 D of usable (20/40 or better) vision.

Overall, increased DOF was observed in 46% of eyes with a single IOL and 54% of eyes with double or triple implants. This difference was not statistically significant, but in cases in which both eyes received primary surgery (*i.e.*, the multiple IOL eye received both implants together, fixated in the capsular bag), 60% of multiple IOL

Figure 1. Primary implantation of a piggyback intraocular lens in the capsular bag



eyes had increased DOF compared with 40% of single IOL eyes.

Shugar *et al.* [13] presented data corroborating the authors' clinical impression. In their study, eyes with multiple acrylic implants demonstrated a substantially greater depth of field compared with eyes with single acrylic implants.

Recently, Findl *et al.* [14] have hypothesized a possible explanation for the increased depth of focus seen in some piggyback eyes. With specular microscopy, they observed a central contact zone between two piggybacked acrylic lenses. The central contact zone contained a darker central zone and was surrounded by concentric Newton rings. The Newton rings presumably represent a thin gap between the lenses that causes interference. The investigators speculate that the darker central zone may be caused by alterations in the optical properties of the acrylic material under pressure.

Figure 2. Insertion of a secondary piggyback intraocular lens into the ciliary sulcus

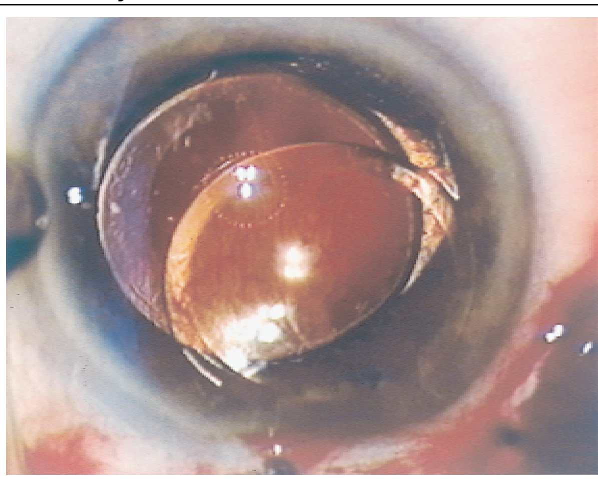
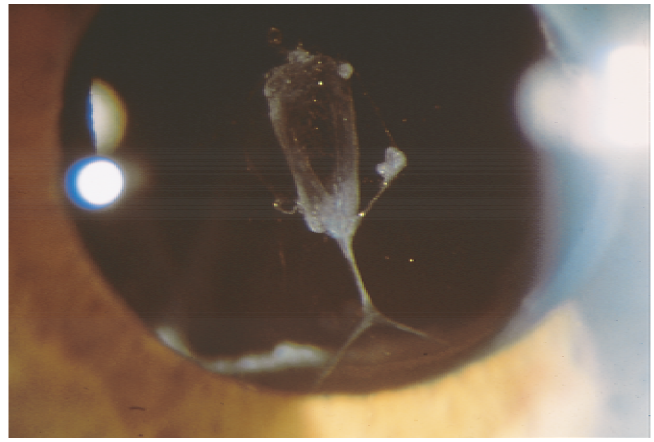


Figure 3. Intralenticular fibrosis between two silicone lenses



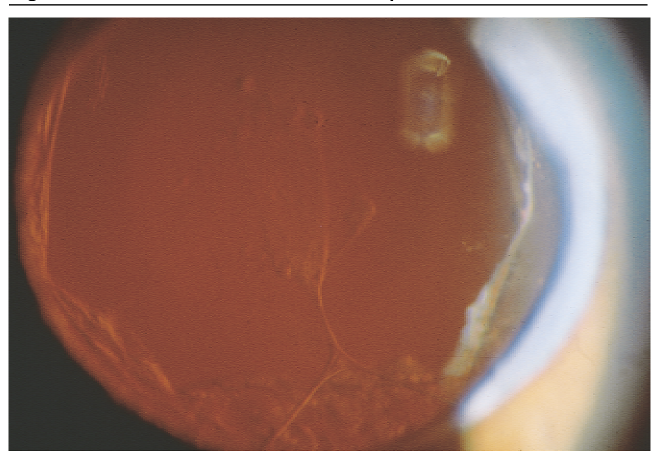
Within the contact zone, the curvature of the lenses changes, resulting in a reduction of refractive power. This lower power zone thus may be used for distance vision, whereas the surrounding zone may be used for near vision. The extent to which a patient with piggyback lenses may experience increased depth of focus caused by a contact zone is variable and is determined by the lens material used and the amount of pressure from capsular contraction.

Complications

Recently, cellular growth between piggyback lenses has become a concern (Fig. 3 and Fig. 4). Shugar and Schwartz [15••] have reported the formation of Elschnig pearls in the peripheral interface of piggybacked acrylic lenses. This growth was associated with late hyperopic shift between 1 and 2 years postoperatively.

Gayton *et al.* [16] have reported a membranous growth between the lens optics of primary piggyback lens sys-

Figure 4. Retroillumination of the same patient



tems occurring more than 2 years postoperatively. These membranes were associated with a loss of best-corrected visual acuity. Although the membrane between a polymethylmethacrylate piggyback system was able to be stripped from between the lenses, in the case of acrylic piggybacks, the membranes were so thick and adherent that the entire piggyback system needed to be removed and exchanged.

Several recommendations have been put forward for avoiding late cellular growth between primary piggyback lenses. First, the capsule should be meticulously cleaned to avoid the presence of epithelial cells that could become attracted to the interlenticular space. Second, the capsulorhexis could be made larger than the lens optic to avoid the migration of cells from the capsular edge to the lens. Finally, one lens could be placed in the sulcus to avoid an interlenticular space that could support such cellular ingrowth.

Conclusions

Although primary piggyback implantation remains applicable for cases with high hyperopia and the rare case of extreme myopia, secondary piggyback implantation to correct pseudophakic refractive error has expanded the application of piggyback lenses. The development of late interlenticular cellular growth in primary piggybacks should be studied carefully and steps taken to avoid the problem in future cases.

References and recommended reading

Papers of particular interest, published within the annual period of review, have been highlighted as:

- • Of special interest
- •• Of outstanding interest

1 Gayton JL, Sanders VN: Implanting two posterior chamber intraocular lenses in a case of microphthalmos. J Cataract Refract Surg 1993, 19:776–777.

2 Gills JP: The implantation of multiple intraocular lenses to optimize visual results in hyperopic cataract patients and under-powered pseudophakes. Best Papers of Sessions, 1995 Symposium on Cataract IOL and Refractive Surgery Special Issue, 1996.

3 • Gayton JL, Sanders V, Van Der Karr M, Raanan MG: Piggybacking intraocular implants to correct pseudophakic refractive error. Ophthalmology 1999, 1066:56–59.
With the implantation of a secondary piggyback lens, the piggyback procedure was extended to address pseudophakic refractive errors in normal and postpenetrating keratoplasty eyes.

4 Gills JP, Fenzl RE: Minus Power Intraocular Lenses to Correct Refractive Error in Myopic Pseudophakes. J Cataract Refract Surg, in press.

5 Gayton JL: Secondary implantation of a double intraocular lens after penetrating keratoplasty. J Cataract Refract Surg 1998, 24:281–282.

6 Holladay JR, Gills JP, Leidlein JL, Cherchio M: Achieving emmetropia in extremely short eyes with two piggyback posterior chamber intraocular lenses. Ophthalmology 1996, 103:1118–1123.

7 Holladay JT, Prager TC, Ruiz RS, Lewis JW: Improving the predictability of intraocular lens power calculations. Arch Ophthalmol 1986, 104:539–541.

8 • Fenzl RE, Gills JP, Cherchio M: Refractive and visual outcome of hyperopic cataract cases operated on before and after implementation of the Holladay II formula. Ophthalmology 1998, 105:1759–1764.
The number of outliers are reduced with the Holladay II formula for piggyback lens power calculation. The accurate results confirm the importance of additional measurements for improved predictability.

9 Loyd TL, Gills JP: Linear regression software for intraocular lens implant power calculation [letter]. Am J Ophthalmol 1986, 102:405–406.

10 • Gills JP: Piggyback minus-power lens implantation in keratoconus. J Cataract Refract Surg 1998, 24:566–568.
The availability of minus-power lenses, combined with the piggyback technique, allows for the correction of even severe myopia in this keratoconus case.

11 Hull CC, Liu CS, Sciscio A: Image quality in polypseudophakia for extremely short eyes. Br J Ophthalmol 1999, 83:656–663.

12 Smith WJ: Modern optical emmetropia: in The Design of Optical Systems. Edited by R Fisher, W Smith. New York: McGraw-Hill; 1966:50–52.

13 Shugar JK, Lee A, Shugar MC: Defocus curves for piggyback acrylic intraocular lenses in highly hyperopic eyes: omniopia? Presented at the Annual Meeting of the American Society of Cataract and Refractive Surgery. Boston, 1997.

14 Findl O, Menapace R, Rainer G, Georgopoulos M: Contact zone of piggyback acrylic intraocular lenses. J Cataract Refract Surg 1999, 25:860–862.

15 •• Shugar JK, Schwartz T: Interpseudophakos Elschnig pearls associated with late hyperopic shift: a complication of piggyback posterior chamber intraocular lens implantation. J Cataract Refract Surg 1999, 25:863–867.
The first indication of possible long-term complications with piggybacks, cell growth between piggybacked lenses is associated with refractive change in acrylic piggybacks. Prevention of the problem would involve a change in surgical technique.

16 Gayton JL, Apple D, Sanders V, Van Der Karr M: Long-term membrane formation between piggybacked implants. Presented at the 25th ASCRS Symposium on Cataract, IOL and Refractive Surgery. Seattle, WA, April 10, 1999.