ABSTRACT

PURPOSE: To evaluate the efficacy, predictability, and safety of three different procedures (intraocular lens [IOL] exchange, piggyback lens implantation, and LASIK) to correct residual refractive error following cataract surgery.

METHODS: A retrospective multicenter study comprised 65 eyes of 54 patients that underwent phacoemulsification, resulting in an unacceptable final refractive error. Eyes were divided into three groups: eyes that had an IOL lens exchange (17 eyes), eyes that had a piggyback lens implanted (20 eyes), and eyes that had LASIK (28 eyes).

RESULTS: No differences between the IOL exchange and piggyback lens groups in the spherical equivalent, sphere, or cylinder were found (P = .072, .436, and .081, respectively). The LASIK group showed a statistically significant reduction in spherical equivalent and refractive cylinder when compared with the IOL exchange group (P < .001 and P = .001, respectively). The LASIK group showed statistically significant reduced refractive cylinder in comparison with the piggyback lens group (P = .002). The median efficacy index was 0.58 (range: 0.28 to 0.93), 0.75 (range: 0.65 to 0.92), and 0.91 (range: 0.85 to 1.14) in the IOL exchange, piggyback lens, and LASIK groups, respectively. Statistically significant differences were found between the IOL exchange and LASIK groups (P = .004) and the piggyback lens and LASIK groups (P = .003). No statistically significant differences were detected in the safety index among groups (P = .094). The predictability (±1 diopters of final spherical equivalent) was 62.5% of eyes in the IOL exchange group, 85% of eyes in the piggyback lens group, and 100% of eyes in the LASIK group.

CONCLUSIONS: The three procedures were effective. The LASIK group showed the best outcomes in efficacy and predictability.

From Vissum Corporation, Alicante, Spain (RF-B, JLA, ALPA, ALQ); Division of Ophthalmology, Universidad Miguel Hernández, Alicante, Spain (JLA); and Institut Universitari Barraquer, Universitat Autònoma de Barcelona, Spain (LPC, RIB).

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Correspondence: Jorge L. Alió, MD, PhD, Avda de Denia s/n, Edificio Vissum, 03016 Alicante, Spain. E-mail: jialio@vissum.com
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of residual ametropia after cataract surgery. Therefore, the aim of this study was to present and compare the results assessing the efficacy, predictability, and safety of three different procedures to correct residual refractive error after cataract surgery: LASIK, IOL exchange, and piggyback lens implantation.

**PATIENTS AND METHODS**

**Patients**

This observational multicenter, retrospective consecutive study comprised 65 eyes of 54 patients that underwent phacoemulsification resulting in an unacceptable final refractive error. Charts of patients from centers of the research group Red Temática de Investigación Oftalmológica (a cooperative network for ophthalmic research subsidized by the Spanish Ministry of Health) with at least 6 months of follow-up and stable refraction were reviewed. The postoperative cataract enhancement procedures were considered in patients with refractive error after uneventful microincision cataract surgery with multifocal IOL implantation who refused to wear corrective lenses and with a normal anterior segment and no capsular opacities or general health problems. The technique in each case was selected by the surgeon depending on the surgeon’s criteria and on the excimer laser availability.

Exclusion criteria included ocular surgery (other than phacoemulsification) or the presence of corneal or other ocular pathology. Informed consent was obtained from all patients before the refractive enhancement procedure. Institutional review board approval was obtained from the local ethics committee.

The eyes were divided into three groups to compare three different surgical techniques. The IOL exchange group comprised eyes that had an IOL exchange with implantation of a new calculated IOL (17 eyes), the piggyback lens group included those cases that had a piggyback lens implanted (20 eyes), and the LASIK group consisted of those eyes that had a LASIK procedure after phacoemulsification (28 eyes).

**Surgical Technique**

The original cataract surgery was performed using phacoemulsification with posterior chamber IOL implantation. The technique included curvilinear continuous capsulotomy and in-the-bag IOL placement.

There was not a standard protocol for the IOL exchange technique. The surgical technique depended on the surgeon’s preference in every case. All IOLs used for exchange were placed in the bag and the same IOL model was used for original implantation and IOL exchange. No toric IOL models were used for the IOL exchange. The IOL power calculation was repeated using the IOLMaster optical biometer (Carl Zeiss Meditec, Inc., Dublin, CA) with the setting “pseudophakic.”

Piggyback lens calculation was performed following the Holladay IOL calculation software (Holladay Consulting, Inc., Bellaire, TX). The IOL implanted in sulcus was the AcrySof MA60 (Alcon Laboratories, Inc., Fort Worth, TX) in all cases.

The LASIK procedures were performed under topical anesthesia with oxybuprocaine 0.4%. Excimer laser ablation was performed in all cases on the stromal bed by means of the Schwind Esiris excimer laser (SCHWIND eye-tech-solutions, Kleinostheim, Germany), using an energy fluency of 180 mJ/cm², a repetition rate ranging from 5 to 50 Hz, and a 0.8-mm flying spot. The optical zone diameter ranged from 6.0 to 6.5 mm and was selected according to the scotopic pupil size and corneal thickness. Temperature and humidity conditions were maintained within the ranges stated by the manufacturer. All procedures were centered at the pupillary center.

Flap creation was performed using the IntraLase 30-kHz femtosecond laser (Abbott Medical Optics, Inc., Santa Ana, CA). Superior hinged flaps with 100-µm thickness were created in all cases.

**Outcome Measures**

The main outcome measures of the study were postoperative uncorrected distance visual acuity, postoperative corrected distance visual acuity (CDVA), and the spherical equivalent (SE), sphere, and refractive cylinder. Other measures studied were the efficacy index (postoperative uncorrected distance visual acuity/preoperative CDVA), safety index (postoperative CDVA/preoperative CDVA), and the predictability. The predictability was evaluated by calculating the percentage of eyes with a postoperative SE within ±0.50 to ±1.00 diopters (D) of the intended correction.

Statistical analysis was performed using SPSS for Windows (version 15.0; SPSS, Inc., Chicago, IL). Nonparametric tests were used to compare the outcomes among groups. Because the number in each group was less than 30, data were expressed as medians. A P value less than .05 was considered significant.

**Results**

The study evaluated 65 eyes of patients with ages ranging from 28 to 82 years old. The IOL exchange group comprised 17 eyes, the piggyback lens group 20 eyes, and the LASIK group 28 eyes. Table 1 shows the preoperative and demographic patient data. There were no statistically significant differences among the three groups in preoperative age, SE, sphere, and refractive cylinder (P > .05; Kruskal–Wallis test) (Table 1). Therefore, the three groups were matched for these variables.
Table 2 summarizes the visual and refractive outcomes before and 6 months after the correcting procedure in each group.

**IOL Exchange**

The IOL models implanted in the original cataract surgery were the following: Acrysof SA60AT (Alcon Laboratories, Inc.) (6 eyes), Acrysof MA60BM (Alcon Laboratories, Inc.) (2 eyes), Acrysof MA30BA (Alcon Laboratories, Inc.) (1 eye), Acrysof SN60WF (Alcon Laboratories, Inc.) (1 eye), Akreos Adapt (Bausch & Lomb, Rochester, NY) (1 eye), AMO Z9002 (Abbott Medical Optics, Inc.) (1 eye), Corneal ACR6D (Groupe Corneal Laboratoires, Paris, France) (1 eye), and unknown model (2 eyes).

The percentage of eyes within ±0.50 D of final SE was 31.3%. When we considered the predictability within ±1.00 D of final SE, 62.5% of the eyes were within these limits. A total of 5 eyes (29.4%) lost one or more lines of CDVA after the IOL exchange surgery.

Six eyes underwent surgery for a myopic correction and 11 eyes for hyperopic correction.

**Piggyback Lens**

In the predictability analysis, 65% of eyes achieved a final SE within ±0.50 D and 85% within ±1.00 D. Seven eyes (35%) lost one or more lines of vision after the piggyback procedure.
Four eyes underwent surgery for myopic correction and 16 eyes for hyperopic correction. Table 3 summarizes the results observed in both subgroups. Regarding the predictability analysis, 75% of the myopic eyes and 68.75% of the hyperopic eyes were within ±0.50 D of final SE ($P = .482$). When the cut point was set at ±1.00 D, 100% of myopic eyes and 81.25% of hyperopic eyes achieved this result ($P = .348$).

LASIK
In this group, 92.85% of eyes showed a final SE within ±0.50 D and 100% of eyes within ±1.00 D. A total of 2 eyes (7.14%) lost one or more lines of CDVA after the correcting procedure.

A total of 15 eyes underwent surgery for myopic correction and 13 eyes for hyperopic correction. Table 3 shows the outcomes in both subgroups.

In the predictability comparison, 93.3% of myopic eyes and 92.3% of hyperopic eyes showed a final SE within ±0.50 D ($P = .916$), whereas 100% of myopic and hyperopic eyes were within ±1.00 D.

Comparative Analysis Among Groups
IOL exchange was the procedure that corrected the highest amount of diopters. In myopia, it achieved a median sphere reduction of 5.75 D and a median SE reduction of 6.12 D. Piggyback lens implantation and LASIK corrected 1.57 and 0.74 D of sphere and 1.50 and 1.00 D of SE, respectively.

In hyperopia, the IOL exchange also achieved the largest correction in sphere and SE, 3.25 and 3.8 D, respectively. Piggyback lens implantation and LASIK corrected 2.37 and 1.88 D of sphere and 2.43 and 1.50 D of SE, respectively.

There were statistically significant differences among the three groups in the SE ($P < .001$) and the refractive cylinder ($P = .001$, respectively). However, there was no statistically significant difference in the sphere ($P = .225$).

When comparing the IOL exchange and piggyback lens groups, no differences in the SE, sphere, or cylinder ($P = .072$, .436, and .081, respectively) were found.

When comparing the IOL exchange and LASIK groups, we found statistically significant differences regarding the SE and the refractive cylinder ($P < .001$ and $P = .001$, respectively). However, there was no statistically significant difference in the sphere ($P = .225$).

Outcomes between the piggyback lens and LASIK groups were also compared. In this analysis, only statistically significant differences in the refractive cylinder could be found ($P = .002$). No differences were found in the SE and in the sphere ($P = .056$ and $P = .751$, respectively).
Figure 3 shows an among groups comparison of the efficacy index. We found statistically significant differences among the three groups ($P = .002$).

A comparison of the efficacy between the IOL exchange and piggyback lens groups was performed and no differences between groups were detected ($P = .271$). We also compared the efficacy between the IOL exchange and LASIK groups. The median efficacy of the IOL exchange group was 0.58 (range: 0.28 to 0.93), whereas in the LASIK group it was 0.91 (range: 0.85 to 1.14). These differences were statistically significant ($P = .004$).

The median efficacy value in the piggyback lens group was 0.75 (range: 0.65 to 0.92). When comparing the piggyback lens and LASIK groups, a statistically significant difference was also found ($P = .003$).

The safety index was analyzed among groups, but no statistically significant differences could be found ($P = .094$). However, the proportion of eyes that lost one or more lines of CDVA was 29.4%, 35%, and 7.14% in the IOL exchange, piggyback lens, and LASIK groups, respectively. In the comparative analysis, these findings were significantly different ($P = .048$). No eye in the LASIK group lost more than two lines of CDVA, but 1 eye and 3 eyes did in the IOL exchange and piggyback lens groups, respectively.

When we compared the predictability, the percentage of eyes within ±0.50 D of final SE was 31.3% in the IOL exchange group, 65% in the piggyback lens group, and 92.9% in the LASIK group. The statistical analysis showed these differences to be significant ($P = .000$).

When we considered the predictability within ±1.00 D of final SE, the outcomes were the following: 62.5% of the eyes in the IOL exchange group, 85% of the eyes in the piggyback lens group, and 100% of the eyes in the LASIK group. These differences were also statistically significant ($P = .003$) (Figure 4).

**DISCUSSION**

Cataract surgery is the most common intraocular surgery performed. Due to the technical progress, the incidence of severe complications has been minimized. Currently, the most common postoperative problems have been reduced to refractive inaccuracies. Postoperative induced astigmatism is usually the most undesired surprise after cataract surgery, although the use of microincisional surgery has significantly improved the control of postoperative astigmatism. Refinement of the refractive outcomes after cataract surgery with excimer laser has been widely described as an effective and safe method. Other alternatives to correct postoperative cataract surgery refractive errors are the lens-based methods IOL exchange and piggyback lens implantation. In a recent study of causes for
pseudophakic IOL exchange, the refractive error was the second most important cause.26 The same results have been shown by both the American Society of Cataract and Refractive Surgery and European Society of Cataract and Refractive Surgeons surveys.27,28 Hence, the refractive error after cataract surgery is a relatively common issue in everyday clinical practice.

In this study, it was shown that the three methods of correction are capable of improving refraction in myopic and hyperopic eyes (Table 3), but not myopic eyes treated by piggyback lens implantation. In this subgroup, although the SE and the sphere were reduced after the surgery, these differences were not significant, probably due to the small sample size.

However, the aim of this study was to compare the three different approaches to determine which approach was the most accurate and safest to correct refractive errors after cataract surgery. In the comparative analysis among groups, statistically significant differences were found in the SE and in the refractive cylinder. When compared with the IOL exchange group, the LASIK group had statistically significant better outcomes for the SE and the refractive cylinder. Significant differences were also detected between the LASIK and piggyback lens groups with the cylinder favoring the former (Figure 2). Therefore, there were no differences in the final sphere among groups. Nevertheless, the cylinder outcome is what makes the LASIK procedure more accurate than the IOL exchange or piggyback lens technique. Refractive cylinder was decreased after surgery in the LASIK group, stable in the piggyback lens group, and increased in the IOL exchange group. We believe the reason for this astigmatic worsening found in the IOL exchange group was that wound enlargement was sometimes required to remove the IOL. The implantation of a toric IOL could be an interesting option to improve the astigmatic outcome when an IOL exchange is planned. We considered that the only limitation for this strategy would be to accurately estimate the amount of induced astigmatism with the wound enlargement.

When analyzing Table 1 and Figures 1-2, we can see a smaller dispersion in the final SE and cylinder of the LASIK group and a wider range in both the piggyback lens and IOL exchange groups. However, it is important to consider that the preoperative range of values was already wider in the IOL exchange and piggyback lens groups and consequently less predictable to handle when compared to preoperative values of the LASIK group.

The efficacy index showed better outcomes in the LASIK group than in the IOL exchange and piggyback lens groups (Figure 3). However, no statistically significant differences were found between IOL exchange and piggyback lens implantation in this index. In the predictability analysis, there were also differences among groups with the best outcome in the LASIK group followed by the piggyback lens group. The worst
predictability was found in the IOL exchange group (Figure 4). It is remarkable that the percentage of eyes within ±0.50 D of final SE in the LASIK group was 92.9%. This result is slightly better than the predictability reported in previous studies.\textsuperscript{10,11,21}

We believe it is necessary to remember that although IOL exchange shows the least accurate results, it was used in those eyes with the largest preoperative residual defects. In fact, in the myopic eyes, the SE reduction achieved in the IOL exchange group was 6.12 D compared to 1.50 and 1.00 D in the piggyback lens and LASIK groups, respectively. In the hyperopic eyes, IOL exchange reduced the SE by 3.80 D, whereas in the piggyback lens and LASIK groups the reduction was 1.88 and 1.50 D, respectively.

Regarding the safety index, no statistically significant differences were found among groups. Nevertheless, the proportion of eyes that lost one or more lines of CDVA was significantly different among groups. This percentage was four to five times higher in the IOL exchange and piggyback lens groups in comparison with the LASIK group (7.14%). Indeed, no eye of those treated with LASIK lost more than two lines of visual acuity, whereas 1 eye in the IOL exchange group and 3 eyes in the piggyback lens group did. Our outcomes in this parameter are worse than those reported in previous studies; we found that close to one-third of patients who underwent surgery with a lens-based method lost one or more lines of visual acuity, whereas another study reported only 11% of eyes.\textsuperscript{15}

To the best of our knowledge, there is only one study comparing these methods used to correct residual refractive defects.\textsuperscript{15} However, in that study the authors established a comparison between LASIK and lens-based correcting methods; including piggyback lens implantation and IOL exchange in the same group. We believe piggyback lens implantation and IOL exchange should not be analyzed together because both surgical procedures are different. In fact, although piggyback lenses may be implanted through a small incision, it is sometimes necessary to enlarge the incision to perform an IOL exchange, resulting in incomparable astigmatic outcomes. However, the authors found comparable results between the LASIK group and the lens-based group in the final SE and safety. On the contrary, our results showed that LASIK is superior to IOL exchange and piggyback lens implantation in final SE, efficacy, predictability, and safety.

Refractive error after cataract surgery is a relevant issue. Although it has been previously mentioned, the intended emmetropia is finally achieved in less than two-thirds of patients.\textsuperscript{14} This explains why it is necessary to know the performance of the methods used to resolve these unsatisfactory situations. The results of this study show that LASIK was the most accurate procedure to correct residual ametropia after cataract surgery. Lens-based procedures (IOL exchange or piggyback lens implantation) are also effective methods and should be the method of choice in those cases with extreme ametropia, corneal abnormalities, or when there is not an available excimer laser platform. A randomized controlled prospective study comparing the three procedures is necessary to confirm these findings.

**AUTHOR CONTRIBUTIONS**

Study concept and design (RF-B, JLA); data collection (RF-B, ALPA, ALQ); analysis and interpretation of data (RF-B, RIB); drafting of the manuscript (RF-B, ALPA, ALQ); critical revision of the manuscript (JLA, LPC, RIB); supervision (JLA, RIB)

**REFERENCES**


**ERRATUM**

This article has been amended to include a factual correction. An error was identified subsequent to its original printing. On page 676 of the article “Resolving Refractive Error After Cataract Surgery: IOL Exchange, Piggyback Lens, or LASIK” by Fernández-Buenaga et al., which was published in the October 2013 issue of the *Journal of Refractive Surgery,* Laura Pinilla Cortés should be listed as Laura Pinilla-Cortés. This error was acknowledged on page 792, volume 29, issue 11. The online article and its erratum are considered the version of record.