Asymmetrical Supracor for hyperopic presbyopes: short term results

José Ramón Soler Tomás, MD, PhD¹; Graciana Fuentes-Páez, MD¹; Sergio Burillo, DDO¹

PURPOSE: To report the pre- and postoperative visual and topographical short-term results in hyperopic presbyopes, following asymmetrical Supracor LASIK.

SETTING: Clinical study at an ophthalmology clinic.

METHODS: A prospective, longitudinal, comparative case series of hyperopic patients with presbyopia treated using the Supracor technique. Preoperative data included dominant (DE) and non-dominant eye (NDE) mono- and binocular distance/near uncorrected and best corrected visual acuities (UCVA, BCVA), addition (Add), spherical equivalent (SE), pupillometry, mean topographic K (Km) and topographic astigmatism. Supracor (LASIK technique) was performed with the DE targeted to emmetropia and the NDE to −0.50 D. Postoperative results: mono- and binocular distance/near UCVA, BCVA, Add, accommodation range, SE, Km, topographic astigmatism and 3.0 mm / 5.0 mm area power. Statistical analysis of pre- and postoperative data included: mean, standard deviation, range, correlation coefficient and Student’s t-test (paired samples) (p ≤ 0.05 for statistical significance).

RESULTS: Twelve patients underwent uneventful Supracor LASIK. We enrolled 5 women and 7 men, mean age 52.2 years. Preoperative monocular distance UCVA was 0.51 ± 0.21, monocular near UCVA 0.40 ± 0.31, binocular distance UCVA 0.51 ± 0.21, binocular near UCVA 0.40 ± 0.25, pupil 5.6 ± 0.7, SE 1.2 ± 0.74, Add 2.0 ± 0.42, Km 43.1 ± 1.2 and topographic astigmatism 0.7 ± 0.4. Postoperative results: monocular distance UCVA 0.91 ± 0.15 (p < 0.001), monocular near UCVA 0.9 ± 0.2, binocular distance UCVA 1.0, binocular near UCVA 0.95 ± 0.13 (p < 0.001), SE −0.26 ± 0.35 (p < 0.001), Add 0.92 ± 0.5 (p < 0.001), Km 44.1 ± 0.9 (p < 0.001) and topographic astigmatism −0.83 ± 0.34 (p > 0.05).

CONCLUSIONS: Asymmetrical Supracor LASIK for hyperopic presbyopes significantly improved distance and near UCVA, both monocular and binocular, while eliminating or reducing spectacle dependence for near vision.

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Monofocal peripheral presbylasik has also been reported as another valuable option for presbyopia. Overall, presbylasik remains a useful tool in the correction of this condition, but further research is still required for its validation. Recently, the CE marked Supracor algorithm for presbyopia in hyperopes, using a biaspHERic multifocal corneal profile designed by Technolas/ZYOPTIX Tissue Saving Algorithm for hyperopia, was validated by our group. The Supracor algorithm performs a central ablation (INTRACOR-like) for near vision (central 3.00 mm zone with target emmetropia for both eyes) and a paracentral ablation for distance vision (multifocal corneal profile over a 6.0 mm optical zone). We report the short-term clinical results in hyperopes with presbyopia, after bilateral treatment with asymmetrical Supracor (dominant eye targeted for emmetropia and a −0.50D target for the non-dominant eye).

**PATIENTS AND METHODS**

This was a prospective, longitudinal, comparative case series of hyperopic patients with presbyopia undergoing Supracor treatment. Patient selection was based on the following inclusion criteria: +1.0D to +2.5D mean refractive spherical equivalent (MRSE), up to 1.0D astigmatism, maximum difference between subjective and cycloplegic refraction ≤ +0.50, and able to tolerate a simulation test of decreased distance vision. Other inclusion criteria were: Km between 42.0D and 44.0D, near addition (Add) ≤ +2.0D required, both eyes with best corrected visual acuity (BCVA) ≥ 0.8 (decimal scale), kappa angle < 10°, no previous corneal surgery and corneal topography suitable for the LASIK procedure, with photopic pupil measurements ≥ 3.00 mm and mesopic pupil within the 4.00 to 6.5 mm range (COLVARD).

Eye dominance (motor) was determined using the “hole in card test”. The patient held a card with a hole in the middle, using both hands, and was asked to view a 6.0 m target through the aperture. The optometrist then occluded each eye alternately to establish which eye was aligned with the hole and the distance target. The selected eye was considered the dominant eye (DE). A trial frame with the best distance correction in both eyes was tested with a +0.50 sphere addition, to simulate the potential blur (DE penalization) induced by multifocality. If visual acuity (VA) was unchanged, or if the patient felt visually comfortable, then he or she underwent asymmetrical Supracor in the DE for distance vision and the NDE for near vision. After standard flap creation with the ZYOPTIX® XP microkeratome (TECHNOLAS Perfect Vision GmbH; Munich, Germany), an asymmetrical SUPRACOR ablation was performed (DE targeted to emmetropia (distance VA) and NDE targeted to −0.50 for near VA) with the Technolas® 217P Excimer Laser (TECHNOLAS Perfect Vision GmbH; Munich, Germany), using a standardized 6.0 mm optical zone. Ocular alignment was aimed between the apex and pupil center, using the ACE Eye tracking System throughout the entire treatment. Data was reported as pre- and postoperative mean and standard deviation (± SD) for monocular and binocular distance/near UCVA, spherical equivalent (SE), subjective refraction, addition, topographic corneal power and topographic astigmatism, at 1 and 6 months. Only patients with at least 6 months of follow-up were included. Postoperative accommodative amplitude (AA) was calculated using the “negative lens” or SHEARD method. The non-examined eye was first covered and a distance subjective refraction was then performed until the patient reached BCVA. A decimal near vision optotype was placed at a distance of 53 cm and once the patient read ≥ 1.0, negative lenses were placed (at 0.25D intervals) until blurred. This value, usually algebraically added to +2.50 (+3.0 minus +0.50 (accommodation lag) = +2.50) was subtracted from the maximum addition required for near BCVA in Supracor patients and considered an indirect measurement of accommodative amplitude.

Safety index (ratio of preoperative and postoperative BCVA, efficacy index (ratio postoperative UCVA and preoperative BCVA), predictability (SE deviation from target refraction), and stability (SE changes at 1 and 6 months) were also calculated.

Microsoft® Excel® 2008 for Mac (121.0 version; 2007 Microsoft Corporation) was used for all statistical analysis of pre- and postoperative data, (mean, standard deviation, range, correlation coefficient, and Student’s t-test —paired samples; p ≤ 0.05 for statistical significance—). Patients with unrealistic expectations (unable to compromise loss of distance vision, seeking perfect vision, very demanding or type A personality) or who did not understand that spectacles could be sometimes required for specific tasks, were not included.

**RESULTS**

Twelve hyperopic patients with presbyopia and near VA spectacle dependence, 7 male and 5 female with mean age 52.2 years, were followed-up for at least 6 months, following an asymmetrical Supracor LASIK procedure for presbyopia. Demographics are shown in Table 1. Mean preoperative results included: distance monocular (0.51 ± 0.21) and binocular (0.4 ± 0.25) uncorrected visual acuity (UCVA), distance/near best corrected visual acuity (BCVA) 1.0 and SE 1.21 ± 0.73. Six DE were right eyes, 6 NDE were left eyes, pupil 5.6 ± 0.7, astigmatism −0.34D ± 0.3, Add 2.0D ± 0.4, Km 43.06D ± 1.2, pachymetry 565μ ± 28 and topographic Km −0.73D ± 0.37. Postoperative monocular visual results and objective data are summarized in Table 2. DE vs. NDE SE results are shown in figure 1.
Figure 1. Postoperative dominant vs. non-dominant eye spherical equivalent. Spherical equivalent was lower for the non-dominant eye, post-asymmetrical Supracor.

Figure 2. Correlation between spherical equivalent and accommodative amplitude. A weak positive correlation was found between SE and accommodation amplitude, i.e. the more negative the SE, the lower accommodation amplitude registered, and vice versa.

Table 1. Demographics for patients undergoing asymmetrical Supracor LASIK for presbyopia.

<table>
<thead>
<tr>
<th>Patients</th>
<th>Gender</th>
<th>Age Mean ± SD</th>
<th>Preop. Pupil in mm Mean ± SD</th>
<th>Ocular dominance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results</td>
<td>5 Women</td>
<td>50.8 ± 1.5</td>
<td>5.6 ± 0.68</td>
<td>OD = 4 / OS = 1</td>
</tr>
<tr>
<td></td>
<td>7 Men</td>
<td>52.2 ± 2.5</td>
<td>5.6 ± 0.40</td>
<td>OD = 5 / OS = 2</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
<td>51.9 ± 2.5</td>
<td>5.3 ± 0.57</td>
<td>OD = 9 / OS = 3</td>
</tr>
</tbody>
</table>

SD, standard deviation; OD, right eye; OS, left eye

Table 2. Postoperative monocular visual results and objective data.

<table>
<thead>
<tr>
<th>Mean Results ±SD</th>
<th>UCVA Distance (decimal)</th>
<th>UCVA Near</th>
<th>Spherical Equivalent</th>
<th>Add</th>
<th>Km</th>
<th>Topographic Astigmatism</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE</td>
<td>0.51 ± 0.21</td>
<td>0.40 ± 0.31</td>
<td>1.2 ± 0.74</td>
<td>2.0 ± 0.42</td>
<td>43.1 ± 1.2</td>
<td>0.74 ± 0.37</td>
</tr>
<tr>
<td>POST</td>
<td>0.91 ± 0.15</td>
<td>0.90 ± 0.2</td>
<td>−0.26 ± 0.35</td>
<td>0.87 ± 0.48</td>
<td>44.1 ± 0.9</td>
<td>−0.83 ± 0.34</td>
</tr>
<tr>
<td>P-value</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>p &gt; 0.05</td>
</tr>
</tbody>
</table>

p < 0.05 statistical significance. Paired T-student. SD, standard deviation.

Pre-and post-asymmetrical Supracor LASIK results were statistically significant, except for topographic astigmatism.

Table 3. Post-asymmetrical Supracor LASIK 3.00-mm area power data.

<table>
<thead>
<tr>
<th>Mean power 0.00 mm zone ±SD</th>
<th>Mean central power ±SD</th>
<th>Mean central minimum power ±SD</th>
<th>Mean central maximum power ±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>1.23 ± 0.72</td>
<td>1.6 ± 0.85</td>
<td>0.75 ± 0.40</td>
</tr>
<tr>
<td>Dominant eye</td>
<td>0.94 ± 0.36</td>
<td>1.2 ± 0.90</td>
<td>0.71 ± 0.40</td>
</tr>
<tr>
<td>Non-dominant eye</td>
<td>1.5 ± 0.57</td>
<td>2.0 ± 0.64</td>
<td>0.8 ± 0.37</td>
</tr>
<tr>
<td>P-value*</td>
<td>p &gt; 0.05</td>
<td>p &lt; 0.05</td>
<td>p &gt; 0.05</td>
</tr>
</tbody>
</table>

*paired Student-t test. SD, standard deviation.

Non-dominant eye mean central power and mean maximum central power were significantly higher than those of the dominant eye.
Overall mean postoperative AA was 0.9 ± 0.42: 1.03 ± 0.3 for the DE and 0.72 ± 0.52 for the NDE (p > 0.05). A positive correlation coefficient was recorded between the final SE and accommodative amplitude (r = 0.27) (Figure 2).

NDE postoperative visual results are shown in figure 3. When comparing monocular distance and near UCVA in the DE and NDE, p was 0.34 for distance and 0.47 for near. DE visual results are shown in figure 4. Binocular distance UCVA was 1.0 for 100% of cases and binocular near UCVA was ≥ 0.8 for 92% of patients. Pre- and postoperative binocular visual results after Supracor are shown in figures 4-6 (p ≤ 0.001).

Central steepening in the 3.0 mm area was observed topographically in all eyes. The overall minimum value was 0.1D and maximum value was 2.8D. Figure 7 shows a patient’s topography, where central steepening is higher for the NDE (2.4D) than for the DE (1.7D). Table 3 lists the mean topographic power data for the central 3.0 mm area for all eyes, DE and NDE. A positive correlation coefficient (0.50) was found between the monocular near UCVA and the 3.00 mm area central power (Figure 8). The correlation coefficient was –0.13 between SE and 3.00 mm area central power (Figure 9).

Mean topographic astigmatism at the 3.0 mm area was 1.0 ± 0.32, and 1.2 ± 0.56 at the 5.0 mm central area. Mean topographic astigmatism at the 3.0 mm area was 1.1 ± 0.4 in the DE and 1.0 ± 0.23 for the NDE (p > 0.05). Mean topographic astigmatism at the

Figure 3. Mean postoperative non-dominant eye visual results, after asymmetrical Supracor LASIK. Post-asymmetrical Supracor, distance UCVA was better for the DE than the NDE.

Figure 4. Mean postoperative dominant eye visual results, after asymmetrical Supracor LASIK. Post-asymmetrical Supracor, near UCVA was better for the NDE than the DE.

Figure 5. Pre- and post-asymmetrical Supracor LASIK binocular distance visual results. Binocular distance visual results improved after asymmetrical Supracor.

Figure 6. Pre- and post-asymmetrical Supracor LASIK binocular near visual results. Binocular near visual results improved after asymmetrical Supracor.

Figure 7. Shows a patient’s topography, where central steepening is higher for the NDE (2.4D) than for the DE (1.7D).
Figure 7. Post-asymmetrical Supracor LASIK central power at 3.00 mm area for dominant (1.8D; right) and non-dominant (2.4D; left) eyes. Central steepening was higher for the non-dominant eye (OD = 2.4D).

Figure 8. Correlation between monocular uncorrected visual acuity and central power; 3.00 mm area. A weak positive correlation was registered between near UCVA and central power, i.e. the higher the near UCVA, the higher the central power found.

Figure 9. Correlation between postoperative spherical equivalent and central power; 3.00 mm area. A weak negative correlation was found between SE and central power, i.e. the lower the SE, the higher the central power found.

Table 4. Post-asymmetrical Supracor LASIK dominant vs. non-dominant results comparison.

<table>
<thead>
<tr>
<th></th>
<th>Distance UCVA ± SD</th>
<th>Near UCVA ± SD</th>
<th>SE (Diopters) ± SD</th>
<th>Accommodative amplitude (Diopters) ± SD</th>
<th>Central corneal power (Diopters) ± SD</th>
<th>3.0-mm area mean power (Diopters) ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant Eye</td>
<td>0.94 ± 0.15</td>
<td>0.85 ± 0.16</td>
<td>−0.08 ± 0.26</td>
<td>1.0 ± 0.26</td>
<td>1.2 ± 0.87</td>
<td>0.94 ± 0.76</td>
</tr>
<tr>
<td>Non Dominant Eye</td>
<td>0.44 ± 0.17</td>
<td>0.94 ± 0.09</td>
<td>−0.41 ± 0.28</td>
<td>0.7 ± 0.52</td>
<td>2.0 ± 0.64</td>
<td>1.5 ± 0.57</td>
</tr>
</tbody>
</table>

*p-value*  
p > 0.05  
p > 0.05  
p < 0.05  
p > 0.05  
p > 0.05  
p > 0.05

*paired t-student; UCVA, Uncorrected visual acuity; SE, spherical equivalent; SD, standard deviation. When comparing results for dominant vs non dominant eyes, statistical significance was found for the spherical equivalent only.

Complications included mild dry eye syndrome in 2 female patients and one DE enhancement due to low distance UCVA (0.5 with a −0.875 SE and 1.0 near UCVA). The latter was performed with a standard Tissue Saving algorithm, after which the distance UCVA improved to 1.0, and 0.8 for near UCVA (−0.25 SE).
**DISCUSSION**

Presbylasik pseudoaccommodation is achieved by shaping a multifocal cornea over a 6.0 mm optical zone. Ruiz was the first to define and coin the term, back in 1996, which resulted in subsequent presbylasik publications. These articles concluded that presbylasik, whether central, peripheral or combined with monovision, is a valid option for VA improvement and spectacle independence in presbyopes.

Alió et al. considered central presbylasik as an alternative for near vision improvement in low-moderate hyperopes, while Ortiz et al. reported an improvement in optical quality, in terms of Strehl ratios, after central presbylasik in hyperopes using a light propagation algorithm. Presbylasik results have also been compared to those recorded after multifocal or accommodative IOL implantation and refractive multifocal IOL simulations.

Central presbylasik techniques, like Supracor, are pupil-dependent and seek the same objective as currently available diffractive intraocular lenses, i.e. spectacle independence for distance, intermediate and near vision. With central presbylasik techniques, near UCVA improvement is immediate, while distance UCVA is only affected at the central hyperpositive area where pupil miosis occurs. The Supracor ablation for presbyopia in hyperopes consists of a central 3.00 mm INTRACOR-like curvature using the ZYOPTIX Tissue Saving Algorithm for hyperopia, hence the importance of limiting this procedure to photopic pupil diameters of at least 3.0 mm, in order to avoid distance UCVA penalization induced by the central bump. The Supracor algorithm first ablates a hyperpositive central curvature and then a paracentral ablation for distance VA, thus providing corneal multifocality. The remaining peripheral ablation is performed over a 6.00 mm optical zone, thereby limiting mesopic pupil diameters to 6.5 mm in order to achieve optimal results. Asymmetrical Supracor patients (target emmetropia for DE and −0.50 NDE) experienced immediate binocular distance and near UCVA improvement. Our Intracor and symmetrical Supracor patients (target emmetropia for both eyes), on the other hand, recovered immediate near UCVA but required several weeks for distance UCVA to improve (unpublished data).

Our asymmetrical Supracor ablation profile provided patients with a mean induced pseudoaccommodation of 1.1D (mean 3.00 mm area power). Mean central power was higher for the NDE than the DE (2.0 vs. 1.2; p > 0.05); an example is illustrated in figure 7, which compares the bilateral central corneal steepening pattern between eyes. NDE central corneal steepening was greater than in the DE (2.4D vs. 1.8D, respectively; p < 0.05), as was near UCVA (0.94 vs. 0.85; p > 0.05). With respect to the mean postoperative addition values, we found a lower mean spectacle near addition than both Alió et al. and Jung et al.: Supracor +0.87 Add after 6 months vs. +1.72D and +1.42D, respectively. The mean 3.0 mm and 5.00 mm area power for the DE was lower than for the NDE (0.9 vs. 1.5D; p = 0.11 and 0.4 vs. 0.5; p > 0.05, respectively).

Topographic astigmatism changes were not statistically significant following asymmetrical Supracor. We concluded that asymmetrical Supracor ablation was quite regular, after finding no statistical significance between the 3.00 mm and 5.00 mm area topographic astigmatisms (overall: 1.0 vs. 1.14D; p = 0.26, DE vs. NDE 1.1 vs. 1.0D; p > 0.05 at the 3.00 mm area and 1.4 vs. 1.1D; p = 0.7 at the 5.00 mm area; p > 0.05).

We recorded 1.0 bilateral distance vision in 100% of cases and ≥ 0.8 in 87% of cases for binocular near VA 6 months after asymmetrical Supracor. All eyes significantly improved monocular UCVA for both distance and near vision. After asymmetrical Supracor, both distance and near vision improvements were statistically significant for monocular and binocular UCVA. In their article on central presbylasik, Alió et al. reported that binocular UCVA results for distance vision were ≥ 20/20 in 60% of cases and ≥ 20/40 in 72%.

Jung et al. reported 0.8 or better binocular distance UCVA and 0.65 or better binocular near UCVA in 64.3% of cases. More recently, Uthoff et al. reported binocular distance UCVA of 0.04 logMAR and 0.24 logRAD binocular near UCVA following PresbyMAX presbyopic correction.

The mean monocular distance UCVA was slightly higher in the DE than in the NDE, while the contrary was recorded for mean monocular near UCVA, although these results were not statistically significant (p > 0.05). A weak positive correlation (r = 0.50) was found between monocular near UCVA and the 3.00 mm area central power.

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**Table 5. Post-Supracor 6-month follow-up. Short-term asymmetrical Supracor LASIK indices**

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Efficacy</th>
<th>SE stability (1 &amp; 6 months)</th>
<th>Predictability (Diopters)</th>
<th>Final SE (Target)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monocular</td>
<td>Far: 1.0</td>
<td>Far: 0.9</td>
<td>DE: −0.13D</td>
<td>DE SE −0.28 (plane)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Near: 1.0</td>
<td>Near: 0.8</td>
<td>NDE: −0.16D</td>
<td>NDE SE −0.53 (−0.50)</td>
<td></td>
</tr>
<tr>
<td>Binocular</td>
<td>Far: 1.0</td>
<td>Far: 1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Near: 1.0</td>
<td>Near: 1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SE, spherical equivalent; DE, dominant eye; NDE, non-dominant eye; D, diopters
Asymmetrical Supracor was shown to be safe (1.0 safety index for near and distance VA) and its efficacy for both binocular distance and near VA was better for binocular UCVA (1.0 for both distance and near UCVA) than monocular (distance 0.9 and near 0.8 UCVA). Both Alió et al. and Jung et al. reported excellent safety indices for both distance and near UCVA, with their respective software.\(^8\)\(^,\)\(^10\)\(^,\)\(^18\) Alió et al. reported a –0.37D short-term SE while we reported an overall mean SE of –0.30D after 6 months for asymmetrical Supracor. DE and NDE SE differences were statistically significant (–0.08D and –0.4D, respectively; p ≤ 0.001). Epstein and Gurgos reported higher SE instability in hyperopic presbyopes when compared to myopes, after monocular peripheral presbylasik.\(^\text{12}\)

NDE predictability was better (target SE –0.50D; final SE –0.53D) than in the DE (target SE 0.00; final SE –0.28D) after 6 months. The PresbyMAX software used by Uthoff et al. also targeted final refractions to –0.50D and finally reported a mean SE of –0.13D.\(^\text{11}\) Ortiz et al., with central presbylasik, and Pinelli et al., with peripheral presbylasik (central ablation for distance vision and peripheral ablation for near), reported mean SE of –0.55D and –0.42D, respectively.\(^,\)\(^\text{20}\) The final SE / AA correlation was weakly positive, thus indicating that the more negative the SE, the lower the AA needed for the same task, and vice versa.

Alió et al. reported retreatment in 12% of their patients and loss of 2 lines of distance BCVA for 28% of patients.\(^8\) We reported enhancement of one NDE (4%) due to low distance UCVA (0.5 with –0.875 SE) in one patient, who improved distance vision after standard Tissue Saving treatment with no lines lost, over the same 6 month period.

Statistically significant changes in SE, central corneal steepening, near UCVA and the positive correlation between near UCVA and central corneal steepening proved that a more pronounced NDE central bump was ablated by the asymmetrical Supracor nomogram.

Our results showed that, after 6 months, asymmetrical Supracor LASIK for hyperopic presbyopes significantly improved distance and near UCVA, both monocular and binocular, while reducing or eliminating spectacle dependence. Asymmetrical Supracor was safe, effective and more predictable for the NDE, in the short-term.

REFERENCES