Individualizing approach to management of refractive errors

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HIGHLIGHTS
Modern refractive surgery offers a wide range of corneal and intraocular methods, based on the latest achievements of science and biotechnology, which allow for an individualized approach to refractive error correction in order to obtain the greatest efficacy and safety of the procedure.

ABSTRACT
The proper choice of the method of refractive error correction is essential for both achieving optimal results and patient satisfaction. This selection should be based on the results of a detailed pre-examination, patient expectations, and the refractive surgeon's personal experience. The article presents the main criteria for selecting the most commonly used corneal and intraocular methods for the correction of all refractive errors.

Key words: refractive surgery procedures, laser in situ, keratomileusis, intraocular lenses, myopia, presbyopia
INTRODUCTION

The prevalence of refractive errors is on the rise worldwide. It is estimated that visual impairment affects 75% of American adults. Myopia affects approximately 25–30% of Caucasians and 80–90% of Asian children and adolescents. Hyperopia and astigmatism affect, respectively, about 15% and 30% of the global population, whereas presbyopia affects over 2.1 billion people worldwide. The most common way of correcting refractive errors are glasses or contact lenses, which are used, by 58% and 14% of people around the world respectively [2].

Higher demands with regard to quality of life have been increasing for years, and the progress observed in biotechnology and medicine has made refractive surgery more popular with growing numbers of corneal and intraocular correction procedures performed each year. The highest number of laser vision correction surgeries are performed in Europe, the USA, Asia and Latin America; it is estimated that about 700 000–1 000 000 procedures are performed worldwide each year. The majority of patients interested in invasive methods of vision correction are young, actively working in professions with strict requirements for uncorrected visual acuity, as well as those with residual refractive errors or astigmatism following cataract surgery. Myopia and myopic astigmatism account for over 80% of laser vision correction procedures [2].

The main principle of corneal refractive surgery is to change the curvature of the anterior corneal surface with laser or intracorneal implants. Anatomically, laser vision correction procedures can be divided into two types: surface and lamellar refractive surgery. Surface ablation refractive surgeries involve removal of the corneal epithelium and ablation of the exposed Bowman's layer and the underlying stroma with an excimer laser. There are different methods of removing the corneal epithelium (chemical, mechanical or with laser) and they include: photorefractive keratectomy (PRK), LASEK (laser subepithelial keratomileusis), EPI-LASIK (epipolis-laser in situ keratomileusis), EBK (epi-Bowman keratectomy) and TE-PRK (transepithelial-PRK). In the latter technique, corneal epithelium is ablated with an excimer laser that provides a regular, circular or elliptical deep epithelialization zone, followed by ablation of the exposed stroma. Lamellar procedures involve dissection of the corneal flap created with a femtosecond laser (FemtoLASIK) or with a mechanical microkeratome (LASIK) followed by ablation of the exposed stroma with an excimer laser [3].

The new Lasik ReLEx (refractive lenticule extraction) technique, also known as SMILE (small incision lenticule extraction), involves femtosecond laser-assisted preparation of corneal stromal lenticule, which is then extracted through a small incision (2–3 mm) [4]. Standard or advanced ablation protocols can be used on wavefront optimized excimer laser platforms. The standard ablation profile shapes the anterior corneal surface based on the spherocylindrical refractive error. On the other hand, advanced ablation protocol (customized ablation) can be topography- or wavefront-guided based on laser-compatible topography and aberrometry. Topography-guided corneal photo-ablation allows for correction of irregular astigmatism or decentralized ablation. Wavefront-guided refractive surgery allows for correction or significant reduction of higher-order aberrations, which impair vision in low contrast and dilated pupil and are the source of undesirable optical phenomena such as glare or halos [5].

Advanced InnovEyes LASIK ablation protocols, programmed with artificial intelligence, are based on mathematical refractive models that include the length of the eyeball, anterior chamber depth, lens thickness, wavefront analysis and accurate CT measurements. Advanced ablation strategies include Laser Blended Vision (LBV Presbyond®), which is currently the most recognized laser correction technique of presbyopia in phakic eyes. This method is based on micromonovision optimized by inducing small values of spherical aberrations and full correction of refractive error in the dominant eye to address distance vision, while the non-dominant eye is mainly corrected for near with a nominal target refraction of -0.75 to -1.50 D. The use of aspheric ablation profile and reduced amount of induced spherical aberrations creates depth of field in each eye and optimizes intermediate vision in the blend zone. LBV Presbyond® technique uses FemtoLASIK or LASIK methods [6]. General characteristics of lamellar and surface ablation procedures are presented in table 1.

Intrastromal corneal ring segments (ICRS), i.e., corneal inlays made of polymethylacrylate (PMMA), are implanted in the mid-corneal peripheral intrastromal tunnels created mechanically or using a femtosecond laser. They are widely used in correcting primary irregular astigmatism caused by corneal dystrophies (keratoconus, transparent marginal degeneration) and secondary astigmatism due to corneal ectasia. The main purpose of using ICRS is to improve uncorrected visual acuity (UCVA) in patients who do not tolerate optical correction well. The advantage of these techniques is that intracorneal implants can be removed. In the last decade, corneal procedures combining intracorneal ring segment (ICRS) or laser-assisted techniques with cross-linking have become more popular [7]. Moreover, intracorneal inlays creating the pinhole effect, different refractive power, or central and paracentral corneal curvature changes [8, 9] can be used to correct presbyopia. However, these techniques are rarely used in practice. There are two types of procedures in intraocular refractive surgery: additional posterior chamber phakic intraocular lens (pIOL) implantation in the eye without removing patient's natural lens [10] and refractive lens exchange (RLE) [11].
Choosing a Method of Refractive Error Correction

Key factors to a successful refractive procedure are the qualifications and experience of the entire team, which translate to proper qualification of the patient, selection of appropriate refractive procedure, its efficient implementation, and effective monitoring of the healing process. The results of detailed examinations allow physicians to assess which treatment method is most optimal and make customized treatment plans that ensure the best effects of refractive error correction. The choice of method depends on many factors such as the type and size of the refractive error, condition of the anterior segment of the eye including cornea and the ocular surface, as well as patient’s age and profession. Before planning laser corneal flap formation it is absolutely necessary to estimate the intact stromal thickness (min. 280–300 μm). The percentage of tissue altered (PTA), which in LASIK and FemtoLASIK is calculated as the sum of flap thickness plus the ablation depth divided by the preoperative central corneal thickness and in SMILE as the sum of lenticule thickness plus the cap thickness divided by central corneal thickness, must be below 40 [12, 13].

Laser vision corrections are most often performed in people over 18 years of age. Although the American Food and Drug Administration (FDA) does not allow for laser refractive procedures in younger patients, performing photorefractive keratectomy (PRK) is acceptable (only in specialized medical centers) in children with high anisometropia, at risk of developing amblyopia, or with severe visual impairment that cannot be corrected with standard methods. There is no upper age limit for laser vision correction; the main contradiction for elderly patients is concomitant eye disease (mainly cataract). Moreover, a higher incidence of residual refractive errors should be taken into account in patients over 60 years of age [14]. Ideal candidates for laser vision correction are adults with a stable refractive error (within +/- 0.5 D in the last 12 months), myopia up to -10 D, hyperopia up to +6 D, astigmatism up to 6 D, anisometropia, and presbyopia.

Currently, FemtoLASIK is the gold standard of refractive surgery due to the largest range of corrected errors, the highest safety during the procedure, and the fastest stabilization of vision. This is the method of choice for treating hyperopia and astigmatism recommended for people over 40 years of age. The FemtoLASIK procedure, as compared to classic LASIK, is more versatile, because it allows surgeons to choose among many different parameters of individualized corneal flap and hinge positions to obtain the greatest efficacy and predictability of the vision correction outcome [15].

FemtoLASIK is recommended for patients with high refractive errors, as well as with relatively thin or flat corneas. The ReLex SMILE® procedure is associated with smaller incisions in the anterior layers of the cornea (as compared to flap techniques), less damage to the anterior stromal layer, faster healing, and reduced postoperative dry eye in FemtoLASIK as compared to LASIK. FemtoLASIK is also associated with a lower risk of developing postoperative corneal ectasia and higher visual stability. FemtoLASIK is recommended for patients over 40 years of age due to its versatility, minimal risk of complications, and faster visual rehabilitation compared to LASIK, PRK, and EPI-LASIK.

TABLE I

<table>
<thead>
<tr>
<th>Procedure</th>
<th>FemtoLASIK</th>
<th>ReLex SMILE®</th>
<th>PRK, LASEK, EPI-LASIK, TE-PRK, EBK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
<td>- faster healing</td>
<td>- efficacy and stability in correcting serious refractive errors</td>
<td>- lower risk of developing postoperative corneal ectasia</td>
</tr>
<tr>
<td>(LASIK)</td>
<td>- faster stabilization of refraction</td>
<td>- less nerve damage and lower risk of developing postoperative dry eye</td>
<td>- lower risk of developing postoperative dry eye</td>
</tr>
<tr>
<td></td>
<td>- efficacy and stability in correcting all refractive errors</td>
<td>- better corneal biomechanical stability</td>
<td>- individualized methods of laser vision correction</td>
</tr>
<tr>
<td></td>
<td>- individualized methods of laser vision correction</td>
<td>- less induction of high-order aberrations</td>
<td>- recommended for patients with recurrent epithelial defects or epithelial basement membrane dystrophy</td>
</tr>
<tr>
<td></td>
<td>- minimal postoperative discomfort</td>
<td>- possible lenticular re-implantation</td>
<td></td>
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<tr>
<td></td>
<td>- minimal risk of corneal haze</td>
<td>- no treatment protocols for hyperopia, mixed astigmatism, and individualized vision corrections</td>
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<tr>
<td></td>
<td>- low risk of infection</td>
<td>- invasive re-correction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- short term use of corticosteroids</td>
<td></td>
<td></td>
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<tr>
<td>Disadvantages</td>
<td>- risk of flap complications (higher in LASIK than in FemtoLASIK)</td>
<td>- possible lenticular re-implantation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- higher risk of developing postoperative dry eye</td>
<td>- no treatment protocols for hyperopia, mixed astigmatism, and individualized vision corrections</td>
<td></td>
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<tr>
<td></td>
<td>- higher risk of developing postoperative corneal ectasia</td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- pain during the first two days after surgery</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>- lower risk of developing serious refractive errors</td>
<td>- slower visual rehabilitation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- higher regression error</td>
<td>- lower efficacy in correcting high, mixed and complex refractive errors</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- higher risk of haze formation</td>
<td>- higher risk of developing postoperative dry eye</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- no sun exposure after the procedure</td>
<td>- higher risk of developing postoperative dry eye</td>
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<tr>
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<td>- long-term topical steroid application</td>
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<td></td>
<td>- higher risk of developing postoperative dry eye</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- higher risk of infectious keratitis</td>
</tr>
</tbody>
</table>

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nerve plexus, and less increase of higher-order and spher-
cal aberrations [16, 17]. This procedure involves longer
docking time of laser interface and the use a lower suction
pressure than in FemtoLASIK. The ReLex SMILE® method
is currently recommended for young patients with myo-
pia and myopic astigmatism who are actively involved
in sports. Due to lower impairment of corneal biomechanics
this procedure should also be considered in patients with
dry eye symptoms, wide pupils, high keratometry values,
well-controlled early glaucoma, and in women planning
a pregnancy.

Surface ablation procedures may be considered in patients
with mild myopia and myopic astigmatism. Best candidates
for these surgeries are patients with relatively thin corne-
as, mild dry eye syndrome, recurrent corneal erosion, or
epithelial basement membrane dystrophy. Moreover, these
techniques can be considered in eyes with borderline val-
ues of keratometry and in patients with deeply-set eyes,
prominent eyebrow arches or practicing contact sports.

The results of meta-analysis comparing the efficacy and
safety of PRK, LASEK, EpilASIK and TE-PRK were as fol-
 lows: LASEK ranked best in terms of efficacy, predictability
and safety. EpilASIK was associated with the lowest level
of postoperative corneal haze, and TE-PRK with the low-
est levels of pain and the shortest epithelial healing time
[18]. On the other hand, other head-to-head meta-analy-
sis comparing efficacy and predictability of PRK, LASEK,
PRK, EpilASIK, sub-Bowman’s keratomileusis (SBK) and
TE-PRK did not confirm the superiority of one procedure
over the other [19–21].

Advanced ablation protocols should be considered in eyes
with irregular astigmatism (topography-guided ablation)
and with complex refractive errors, including higher order
aberrations (wavefront-guided ablation) [5]. When plan-
ning the above procedures, surgeons should remember that
the volume of the ablated corneal tissue is higher in the case
of customized ablation as compared to standard spherico-
cylindrical ablation.

Best candidate for laser blended vision surgery (LBV Pres-
byond®) would be patient above 40 years of age with myopia
up to -8.0 D, hyperopia up to +4.0 D, astigmatism up to
2.5 D, and who passes the cross-blur test. The test deter-
mines which eye is dominant, verifies patient’s tolerance of
anisometropia and assesses visual comfort. LBV Presbyond®
method can also be considered in patients with emmetro-
trope to improve their near vision [22].

Ideal candidates for phakic intracorneal implants are main-
ly young people (above 21 years of age), with high refrac-
tive error, in which laser correction and corneal refractive
surgery are contraindicated. The following criteria must be
met to implant a phakic lens: proper endothelial density
(min. 1900 cells/mm²), minimum anterior-chamber depth
of 3.0 mm (measured between the central anterior lens cap-
sule and the endothelium), and the correct filtration angle.
The range of refractive errors corrected with phakic lenses
is up to -23.0 D (ICL up to -18.0 D) in myopia, up to +12.0
D (ICL up to +10.0 D) in hyperopia, and up to 8.0 D (ICL to
6.0 D) in astigmatism [10]. In the near future, phakic lenses
will be available for patients with presbyopia. The ranges of
refractive errors corrected laser and phakic lenses are pre-
sented in table 2.

Refractive lens exchange and implantation of a multifocal
or a monofocal lens (spherical or toric) can be considered
in presbyopic patients with distant and near vision defects,
without concomitant cataract, and in those who are not
eligible for laser vision correction [11]. Good candidates
for RLE procedure want to be independent from glasses
to far and near, have an optimistic attitude to life and are
willing to accept small difficulties with distance vision.

Patients qualified for RLE should be thoroughly informed
about the risk of surgery, especially of low light vision
disorders, such as glare and halos. Patients with moder-
ate and high hyperopia or myopia, who do not spend long
hours looking at the screen, are the most satisfied with the
outcomes of RLE procedure. The refractive surgeon
should discuss with the patient reasons for vision correc-
tion, as well as patient’s expectations of the procedure tai-
lored to patient’s lifestyle and work. The chosen method
of surgery should guarantee the best possible correction
of the refractive error, taking into account the applicable
safety criteria and patient qualification requirements.
The patient should be informed about the planned procedure,
including its efficacy and safety, as well as about tempo-
rary ailments and changes in the quality of vision that
can be expected initially after surgery, depending on the
method used and the type of refractive error.

A presbyopic patient eligible for LBV Presbyond® laser
surgery should be informed that after presbyopia correc-
tion, the time of neural adaptation and vision stabilization
depends on individual’s capabilities and can last from sev-
eral weeks to several months. At that time and even later,
some activities performed at extreme distances may require
periodic vision correction with glasses. Since refractive er-
rors usually change along lifespan, patients may need to
wear glasses in the future or, if possible, repeat the proce-
dure. People aged 40 years and older who do not qualify
for the simultaneous correction of presbyopia and hypero-
pia, or who plan distance vision correction only, should be
informed about the necessity to wear glasses to near after
the procedure [23]. If the local and general condition of the
patient, as well as their lifestyle and professional needs indi-
cate that IOLs might be more effective and safer than laser
surgical correction, the patient should be informed about
such treatment options [24, 25].
Following refractive surgery, regardless of the method used, patients should follow doctor’s recommendations, adhere to the hourly schedule of eye drops administration, and attend follow-up appointments. Moreover, patients should be informed about alternative, non-invasive methods of correcting refractive errors, i.e., glasses or contact lenses.

CONCLUSIONS
Choosing the right vision correction procedure is essential to achieve optimal visual outcomes and patient satisfaction. The choice should be made taking into consideration detailed assessment questions, patient’s expectations and refractive surgeon’s experience.
References

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Joanna Wierzbowska: choosing a topic, developing concept of the work, collecting literature, preparation of the manuscript and the final version of the manuscript (60%);
Marcin Smorawski: collecting literature, preparation of the manuscript (20%);
Dominik Uram: collecting literature, preparation of the manuscript (20%).

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