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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 expectationsand 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, active, 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 deepithelialization 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 polymethacrylate (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].

TABLE 1

General characteristics of deep and surface ablation procedures.

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

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 the 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 nerve plexus, and less increase of higher-order and spherical 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 myopia 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 corneas, mild dry eye syndrome, recurrent corneal erosion, or epithelial basement membrane dystrophy. Moreover, these techniques can be considered in eyes with borderline values 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, Epi-LASIK and TE-PRK were as follows: LASEK ranked best in terms of efficacy, predictability and safety, Epi-LASIK was associated with the lowest level of postoperative corneal haze, and TE-PRK with the lowest levels of pain and the shortest epithelial healing time [18]. On the other hand, other head-to-head meta-analysis comparing efficacy and predictability of PRK, LASEK, PRK, Epi-LASIK, 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 planning 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 sphero--cylindrical ablation.

Best candidate for laser blended vision surgery (LBV Presbyond®) 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 determines which eye is dominant, verifies patient's tolerance of anisometropia and assesses visual comfort. LBV Presbyond® method can also be considered in patients with emmetropia to improve their near vision [22].

Ideal candidates for phakic intracorneal implants are mainly young people (above 21 years of age), with high refractive 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/mm^2), minimum anterior-chamber depth of 3.0 mm (measured between the central anterior lens capsule 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 presented 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 moderate 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 correction, as well as patient's expectations of the procedure tailored 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 temporary 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 correction, the time of neural adaptation and vision stabilization depends on individual's capabilities and can last from several 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 errors usually change along lifespan, patients may need to wear glasses in the future or, if possible, repeat the procedure. People aged 40 years and older who do not qualify for the simultaneous correction of presbyopia and hyperopia, 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 indicate that IOLs might be more effective and safer than laser surgical correction, the patient should be informed about such treatment options [24, 25].

TABLE 2

The ranges of refractive errors corrected with laser and phakic lenses.

	Myopia	Hyperopia	Mixed astigmatism
LASIK/FemtoLASIK	Up to -10,0 D (-14,0 D according to FDA), with astigmatism up to -5,0 D (ES -10,0 D)	Up to +6,0 D, with astigmatism up to +5,0 D (ES +6,0 D)	Up to 6,0 D
LASIK/FemtoLASIK wavefront-guided	Up to -8,0 D, with astigmatism up to -4,0 D (ES -8,0 D)	-	-
LASIK/FemtoLASIK topography-guided	Up to -8,0 D, with astigmatism up to -3,0 D (ES -9,0 D)	-	-
LASIK/FemtoLASIK Presbyond	Up to -8,0 D, with astigmatism up to -2,5 D (ES -8,0 D)	Up to +4,0 D, with astigmatism up to +2,50 D (ES +4,0 D)	Up to 2,5 D
PRK/LASEK	Up to -10,0 D (-12,0 D according to FDA), with astigmatism up to -4,0 D (ES -10,0 D)	Up to +5,0 D, with astigmatism up to +4,0 D (ES +5,0 D)	Up to 6,0 D
SMILE	Up to -10,0 D, with astigmatism up to -5,0 D (ES -10,0 D)	-	-
Phakic intraocular lenses	Up to -18,0 D, with astigmatism up to -6,0 D (ES -18,0 D)	Up to +10,0 D, with astigmatism up to +6,0 D (ES +10,0 D)	Up to 6,0 D

D – diopter; SE – spherical equivalent.

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.

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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.

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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%);
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