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Professional paper

The Current State of Refractive Surgery

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A B S T R A C T

The leading topic of this particular paper is dedicated to available surgical options for refractive eye disorders treatment including surgery of cornea and intraocular surgery. Corneal Surgery includes laser refractive surgery – LASIK (Laser-Assisted In Situ Keratomileusis), FemtoLASIK (Femtosecond laser – assisted LASIK), PRK (Photorefractive keratectomy). This article describes relevant principles of particular procedures, indications and possible contraindications. The chapter dedicated to corneal implants provides information about ICRS (Intrastromal Corneal Rings Segment) and Inlays (corneal implants for presbyopia correction). Corneal interventions also include incision methods for astigmatism correction AK (Astigmatic Keratotomy) and LRI (Limbal relaxing Incisions). Intraocular refractive interventions preserving natural human lens also include phakic lenses. Relevant categorization, examples, indications and contraindications are listed in particular chapter of this paper. Intraocular refractive surgery which replaces the original human lens is also called RLE (Refractive Lens Exchange) or PRELEX (Presbyopic Lens Exchange). These interventions are usually accompanied with the multifocal intraocular lens implantation. This chapter provides the list of specific lens types, indications and contraindications related to this type of intervention. The last chapter describes Bioptics – the combination of corneal and intraocular surgery.

***Key words**: laser refractive surgery, PRK, LASIK, Femtosecond laser, Phakic intraocular lenses, RLE, PRELEX, ICRS, LRI, bioptics*

Introduction

People live much more active lives when compared to past. This also reveals more significant demands on seeing itself. More and more clients ask to be able to see without glasses which are considered to be limitary in case of many activities. Contact lenses represent the possible alternative for glasses correction. Though, there is a wide group of people unable to withstand the foreign object in the eye and therefore the vision in unstable. This explains the increase of call within the surgery treatment of refractive disorders. Refractive surgery is one of the most dynamic field of ophthalmology which basic function is the microsurgery treatment of refractive eye disorders such as myopia, hyperopia, stigmatism, hight – order aberrations a presbyopia. There is a wide range of available methods for us to make the client free of glasses, and it is even possible to remove severe disorders which were untreatable in the recent years. It is necessary to choose the most appropriate surgery method for each individual subject upon his/her type and range of the dioptric disorder, age, eye parameters, actual lens and retina condition, and according to subject's needs and demands. In case of more complex disorders it is necessary to provide the combination of different surgery interventions. This paper provides the survey of available methods which are used most frequently in ophthalmology to treat refractive eye disorders.

Preoperative assessment

The fundamental part of the appropriate refractive surgery method selection and also the post-surgical satisfaction of the subject is the Preoperative assessment (examination) which includes several steps:

Medical History (questionnaire and discussion with physician) – personal and family history, past and actual disorders, drug history, pregnancy/lactation, refractive history (stable refraction), contact lens wear, corneal ectatic disease, corneal dystrophies, dry eye, previous injury, surgery, keratitis, vision preference, hobby, occupation, vehicle driving, specific demand, client motivation, etc.

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Objective refractive disorder examination – using the autorefracto-keratometry

Subjective refractive disorder assessment – monocular subjective refraction (optotype, cylindrical portion using the Jackson´s crossed cylinders, R/G test), binocular refraction with polatests + additional tests for monocular correction under binocular conditions

Cycloplegic refraction

Biometry – optical / ultrasound: keratometry, axial eye length, depth of the anterior chamber, corneal diameter.

Cornea analysis – corneal topography and tomography (for example: Pentacam) – keratometry of anterior and posterior surface, corneal thickness (pachymetry) anterior chamber depth measuring, densitometry of lens, diagnostic of keratoconus.

Wavefront analysis – aberrometry, measures of lower and higher – order aberrations

Lacrimal film examination (Schirmer test, BUT – break-up time test,..)

Measuring of intraocular pressure (tonometers)

Examination of anterior and posterior ocular segment – slit lamp

Other examination according to relevant findings (endothelial microscopy, perimetry, OCT – Optical coherence tomography,...)

Basic survey of refractive surgery

Corneal refractive surgery – methods included in this section are designed to modify the corneal curvature and therefore its vergency.

Intraocular refractive surgery – interposes new optical objects or includes the replacement of the original human lens.

Laser Refractive Surgery / Laser Vision Correction (LVC)

Includes different methods providing the change of corneal curvature. The best results are within methods using an excimer laser to photoablation of stromal tissue – Surface ablations (PRK-photorefractive keratectomy, LASEK – laser sub-epithelial keratomileusis, Epi-LASIK – epipolis-Laser in Situ Keratomileusis), LASIK (Laser in Situ Keratomileusis) / All-laser-LASIK (femtosecond laser-assisted LASIK / FemtoLASIK). Currently, these methods provide adequate accuracy, safety, stability and predictability[1–8]. This chapter provides the survey of the most frequently used methods.

General contraindications of laser surgery

Relative – tissue disorders and vasculitis (rheumatoid arthritis, lupus erythematodes…), diabetes mellitus, keratoconjunctivis sicca, herpetic keratitis, keratoconus.

Absolute – uncontrolled tissue disorders and vasculitis (rheumatoid arthritis, lupus erythematodes…), Sjogren syndrome, etc. with the severe dry eye syndrome, actual eye inflammation, corneal anesthesia and lagophtalmus

PRK

This approach represents the most frequent method of laser refractive intervention. It is performed on the upper part of the cornea after epithelium removal (using alcohol or abrasion). This causes the separation of epithelium and the basal membrane. The actual treatment of the refractive errors is provided through the evaporation of the corneal stroma using the excimer laser. Covering contact lens is places on the eye after the surgery which provides save and adequate epithelization of the cornea (renewal of the epithelium layer).

Advantages: technically and technologically simple, cornea incision free method, preserves the stromal tissue, the oldest method = widest range of experience

Disadvantages: post-operative feel of cutting, feel of burning, tearing, occasional pain, longer rehabilitation of the vision, longer application of corticosteroids.

PRK indications: myopia (up to 6 Dsf), hyperopia mostly not (if applied – up to +3 Dsf), astigmatism (up to 3 Dcyl), in case LASIK in contraindicated, anterior corneal dystrophy, adequate quality of the lacrimal film.

LASIK

Currently the most frequent method of the laser refractive surgery. The main difference when compared to PRK is in flap formation in upper layers of the cornea. Flap contains epithelium, Bowman´s membrane and small part of the stroma. The next step is similar to PRK and proceeds with the actual treatment of the refractive error using the excimer laser in the area of the stroma. The lamella is then repositioned back to modified corneal surface. Usually the covering contact lens is not necessary.

Flap formation with the microkeratome – Flap is created with the device called microkeratome. In principle it is a computerized vibrating razor.

Flap formation with the femtosecond laser (All-laser LASIK/ Femto LASIK): low-energy laser with extremely short impulses and high repetitive frequency. This technology provides highly tissue preserving „cut«. The effect of evaporation is present on the actual focus of the laser beam (micro-evaporation), which leads to tissue separation.

Advantages: wide indication range, fast renewal of vision, minimal or no post-surgery pain.

Disadvantages: possible damage to corneal flap (incomplete flap, free cap, button hole – lower risk in case of femtoLASIK)

Iindications: hypometropia (up to –10 Dsf), hypermetropia (up to +5 Dsf), astigmatism up to 5 Dcyl, adequate quality of the lacrimal film.

Worldwide, an average 95.4% of patients were satisfied with their outcome after LASIK surgery. With 16.3 million procedures performed worldwide, and more than a decade of clinical studies and technological innovation, LASIK surgery should be considered among the most successful elective procedures. LASIK surgery compares

more favorably with other elective surgical procedures in terms of generally higher satisfaction rates. [9]

Advantages of the femtosecond lasers: Tissue preserving devices, modern technology, more precise performance, high tolerance (lower vacuum level when compared to microkeratome), lower risk of post-surgery dry eye syndrome[10], wider indication spectrum (flatter and abrupt corneas), hinge position available (nasal, superior,...), better accuracy of flap thickness and lower risk of flap-related complications[11–14].

The future of the eye surgery is within the femtosecond lasers. As a reference we provide the actual usage of these devices:

- Corneal lamella (LASIK, lamellar keratoplasty, penetration keratoplastic)
- Corneal tunnels for ICRS (e.g. Kerarings)
- Myopia treatment (FLEX – femtosecond lenticulus extraction)
- Cataract surgery (corneal incisions, capsulorhexis, initial fragmentation of the lens core) – together with the anterior segmented optical coherence tomography – OCT)

ICRS

This technique is provided through intrastromal corneal rings used within the therapy of keratoconus (pathological buckling of the cornea). They are designed to flatten and stabilize the cornea. Its actual benefit is in reduction of an extreme astigmatism which causes this disorder and also provides improvement of the visual acuity[15–17].

These implants are embedded into ring tunnel localized in the corneal stroma. The tunnel can be made using mechanical device or using femtosecond laser. The actual size and number of inserted rings depend on the particular case. Rings are made of hard acrylate.

Inlays

This term represents corneal implants embedded into corneal stroma and designed for presbyopia correction (physiological condition due to accommodation reduction). Generally, these implants provide correction for reading. The surgery is similar to LASIK within the first phase. Surgeon creates adequate lamella and inserts Inlay into the space between lamella and stroma. The actual performance of these implants is provided through multifocality principle or through stenopeic opening (e.g. KAMRA (AcuFocus)–diameter 3.8 mm, opening diameter 1.6 mm. The actual advantage of the inlay technique is the improvement of the visual acuity on short and long distances, and the combination with the excimer laser which provides the possibility of correction for people with presbyopic emetropia, hyperopia and myopia[20].

Incision methods

Astigmatic keratotomy (AK): The cornea incision technique for astigmatism correction. This method uses the diamond knife with the adjustable incision depth and provides cutting of the cornea in different lengths and meridians. All relevant parameters are individual within each subject. The actual result of this technique is the flattening in the steepest meridian and buckling within the flat plane. The actual disadvantage of this technique is particularly bad predictability of the result.

LRI – limbal relaxing incision: This method is technically comparable to AK. It is used to treat low astigmatism (app. up to 2 cyl.), usually together with the lens surgery[21,22]. By contrast to AK, it is performed on the periphery and in the area of the surgical limbus. This method provides better predictability but is less effective when compared to AK. It is necessary to say, that both cornea incision methods are recessive. They are replaced by modern refractive lasers and toric intraocular lenses.

Intraocular Refractive Surgery

Phakic intraocular lenses

Contrary to laser techniques, which change the corneal curvature and therefore the final vergency value of the optical system, the implantation of the phakic lens completes the dioptric force of the human lens which persists in the eye. Phakic lens is implanted through the small corneal incision into the eye and in front of or behind the pupil. This method uses artificial implants which are made of compatible material inserted into the eye while the original human lens is preserved. In advance defined dioptric force of the implanted lens provides the possibility to modify wide range of dioptric disorders and provides high quality vision and preserves the accommodation ability of the eye. Current market provides wide range of implants but this paper is dedicated to those which are frequently used worldwide and proved with the best results[23–30].

Indications: myopia, hyperopia, astigmatism, impossibility to use laser surgery with excimer laser (e.g. thin cornea, keratoconus), preserving of the natural lens accommodation.

Contraindications: Corneal or endothelial pathology, glaucoma, uveitis, pigment dispersion syndrome, PEX syndrome, narrow chamber angle, cataract.

Advantages: wide range of indications (–25D to +10D), quick recovery of vision, high accuracy of the result even in case of high disorders, minimal adverse effects, possible combination with laser refractive surgery (bioptics), reversibility of the surgery (possibility to restore original condition)

Visian ICL (Implantable Collamer Lens)

Posterior chamber lens

Indications – myopia, hyperopia, astigmatism (dioptric range: –0.5 to –18.0, +0.5 to +10.0, cylinder +0.5 to 6.0)

Advantages: biocompatible material – Collamer, 4 body fixation (minimal traumatizing of retropupilar structures), optical zone up to 5.8 mm, implantation with incision up to 3.0 mm – no suture

Artisan/Artiflex

Anterior chamber »iris claw« lens (iris-fixated). Artisan – rigid, Artiflex – foldable.

Indication – myopia, hyperopia, astigmatism (dioptric range –1.0 to –23.5, +1.0 to +12.0, cylinder 1.0 to 7.5)

Advantages: – biocompatible material – PMMA (Artisan), Polysiloxane (Artiflex), 2 fixation points on iris – iris claw, optical zone up to 6 mm, higher dioptric range.

Disadvantage: necessity of pre-surgery laser iridotomy or per-surgery iridectomy, implantation with incision 5 to 6 mm and with suture in case of Artisan lens, risk of iris ovalization

AcrySof Cachet

Anterior chamber lens

Indication – myopia (dioptric range –6.0 / –16.5D)

Advantages: biocompatible material – hydrophobic acrylate AcrySof, 4 fixation points (minimal traumatizing of chamber angle), wide optical zone 6.0 mm, no need of pre-surgery laser iridotomy or per-surgery iridectomy, implantation with incision up to 2.6 mm – no suture

The disadvantage is lower dioptric range and single myopic variant without any astigmatism correction option.

RLE (Refractive Lens Exchange)

This method is based on actual replacement of human lens for artificial implant. Technical aspect of this surgery is concordant to cataract surgery. Contrary to cataract surgery, this method remove clear lens which is unable to accommodate. Current modern method for human lens removal is based on ultrasound technology (USG). Even improved method uses femtosecond laser under RLE, which is able to generate precisely centred capsulorhexis and initially fragmented lens. Artificial lens is then implanted instead of original lens. Currently used lenses are soft and implanted using injector with minimal admission port while wounds are left without suture. The actual value of the artificial lens is calculated according to biometry (usually optical or ultrasound technique) and based on keratometry; provided eye parameters are used to calculate necessary dioptric power of the implant.

Indications: myopia, hyperopia, astigmatism, presbyopia, subjects over 40 years of age.

Advantages: the widest range of indication, high accuracy, permanent solution, presbyopia treatment.

Lens types for RLE:

- Monofocal – (treats correction of one distance according to client demand)
- Monofocal aspheric (better contrast sensitivity[31], similar to above listed type – treats one distance only
- Toric (for current correction of astigmatism[32,33])
- Accommodation (this type is able to act like original lens up to certain level and during certain period of time)
- Multifocal (treatment of »all« distances)
- Multifocal toric (multifocal lenses for eyes with astigmatism)
- Trifocal – advantage of better visualization on middle distance (computer monitor)

Following terminology is often used to define implantation of multifocal intraocular lens – PRELEX (Presbyopic Lens Exchange). The actual design of the intraocular lens can be based on refractive principle (beams formation) or on difractive principle. It is possible to use them as monocular implant, into one eye, or into both eyes. The actual physical character of these lenses differs from the original human lens, therefore each client should be prepared to get used to this correction which requires certain amount of time (neuroadaptation).

Successful implantation of the multifocal lens requires correct function of the pupil and healthy retina. This type of correction provides comfortable vision on most distances[34–43]. This procedure eliminates the risk of cataract development. The most significant disadvantage of this method is side optical phenomenon, e.g. halo effect (rings depicted around light sources) or glare (defocusing fields around light sources)

Bioptics

Combines several types of refractive procedures. All procedures are accomplishable upon one session or it is possible to separate them into two or more sessions with relevant time gap.

This method is indicated for high disorders correction or in case of primary surgery post-correction[44–47].

The most frequent indication: laser post-correction after primary RLE, laser post-correction after primary implantation of phakic lens, combination of RLE and LRI, combination of phakic lens implantation with LRI.

Conclusion

Due to wide range of refractive procedures we are able to treat each type of high refractive errors. The actual choice of the particular method is strictly individual and available surgery procedures can be combined. This technological advance within the field of refractive surgery means: safety, accuracy, efficiency, excellent vision results during the first day after surgery, high quality of vision, stability and satisfied patients.

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DANAŠNJE STANJE REFRAKTIVNE KIRURGIJE

SAŽETAK

Glavna tema u ovom radu je pristup kirurgije rožnice i intraokularne kirurgije u rješavanju refraktivnih grešaka oka. U kirurgiji rožnice uključen je LASIK, FemtoLASIK i PRK. Posebna pažnja u ovom radu posvećena je kornealnim implantima u korekciji presbiopije. Opisuje se i kornealna incizija u kirurškoj korekciji astigmatizma, intraokularne implantacije IOELa s naglaskom na multifokalne intraokularne leće. U ovom radu opisuju se karakteristike pojedinih tipova IOELa sa indikacijama i kontraindikacijama. Također je prikazan kirurški tretman u kombinaciji kirurškog zahvata na rožnici i intraokularne kirurgije.