Review

Predicting Success: The Crucial Role of Preoperative Data in Refractive Surgery Outcomes

Ann. Ital. Chir., 2025 96, 1: 19–28
https://doi.org/10.62713/aic.3778

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Refractive surgery, which includes techniques such as Laser-Assisted *In Situ* Keratomileusis (LASIK), Photorefractive Keratectomy (PRK) and Small Incision Lenticule Extraction (SMILE), has revolutionized ophthalmology by offering advanced solutions for vision correction. However, the choice of the technique to be used in the individual patient is highly dependent on a thorough preoperative evaluation. This retrospective study aims to investigate how preoperative parameters, including corneal thickness, topography, and refraction, affect long-term post-operative clinical outcomes. Through a systematic review of the literature published between 2000 and 2023, we identify the main predictors of success for each surgical technique. This study emphasizes the importance of personalized surgical strategies based on meticulous preoperative analysis.

Keywords: refractive surgery; LASIK (Laser-Assisted *In Situ* Keratomileusis); PRK (Photorefractive Keratectomy); SMILE (Small Incision Lenticule Extraction); preoperative assessment; corneal topography; customized surgical approaches; success predictors

Introduction

Refractive surgery is one of the most performed procedures in modern ophthalmology, as it offers an often permanent solution to the most common refractive disorders such as myopia, hyperopia and astigmatism.

With millions of patients choosing to have their vision corrected each year, refractive surgery has become as one of the most popular elective procedures carried out globally in recent years. More than 2 billion people worldwide suffer from refractive defects, which include disorders like myopia, hyperopia, and astigmatism. Although each method presents distinct benefits, there is an urgent want for standardized preoperative criteria to enhance results. Laser-Assisted *In Situ* Keratomileusis (LASIK) continues to be the most widely used surgical correction technique, making up more than half of all refractive procedures performed in North America and Europe. Photorefractive Keratectomy (PRK) and Small Incision Lenticule Extraction (SMILE) are also commonly used; SMILE is becoming more popular in Asia, where myopia rates are among the highest in the world [1]. The need for standardized preoperative evaluations to guarantee safe and ideal results for this growing patient population is further supported by these figures, which highlight the rising demand for efficient, customized surgical procedures in refractive care. All these techniques offer a safe and durable alternative to glasses and contact lenses, significantly improving the quality of life of patients who choose to resort to surgical correction [2]. Refractive surgery has evolved and improved significantly over the years, from its first applications with radial keratotomy to new and modern laser-based techniques that provide greater precision and a lower risk of developing both intra- and post-operative complications. However, despite numerous technological advances and standardization of surgical procedures, uncertainty about post-operative outcomes in a subset of patients remains. In addition, some complications such as corneal ectasia, refractive regression and persistent dry eye symptoms continue

Submitted: 29 September 2024 Revised: 4 December 2024 Accepted: 17 December 2024 Published: 10 January 2025
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to represent real challenges that have not been fully resolved. These aspects underline the fundamental importance of carrying out a very thorough and personalized preoperative evaluation to try to optimize surgical results as much as possible. Advances in preoperative diagnostic technologies, such as aberrometry and corneal tomography, have greatly enhanced the precision with which surgeons can plan and execute refractive procedures. However, despite the numerous advances of these techniques, there is still no real and shared standardization of some preoperative parameters, such as corneal thickness thresholds and pupil size measurements, which are fundamental parameters to guide surgery and consequently minimize postoperative complications [3]. In addition, there is limited data to date on the long-term outcomes of how preoperative aberration measurements affect postoperative visual quality, particularly in specific patient populations. The accuracy of preoperative assessment has become increasingly important to ensure optimal post-operative outcomes [4]. The main preoperative data analyzed include corneal topography, pachymetry (corneal thickness), higher-order aberration measurements, and pupil size. Each of these parameters makes it possible to determine the patient's suitability for refractive surgery [4]. Personalized approaches have been shown to improve surgical outcomes and reduce postoperative complications. However, to date there is significant variability in preoperative evaluation tests, with considerable differences in the different protocols used to collect and analyze the data of individual patients who want to undergo refractive surgery. The lack of shared consensus and uniformity on fundamental aspects such as corneal thickness thresholds and optimal ablation zone size underscore the need to develop shared standardized protocols. This review aims to analyze the literature available to date on the importance of preoperative data in trying to predict the outcomes of refractive surgery. In particular, it will focus on the evaluation of corneal topography, corneal thickness, ocular aberrations and pupil size as key factors influencing the choice and success of surgery. This work delineates novel methodologies in predictive analytics for preoperative assessment, differentiating it from previous research. References were chosen for their relevance to the study's emphasis on predictive characteristics and clinical outcomes, prioritizing studies published in high-impact journals during the last five years. This selection method guarantees thorough coverage of developments in preoperative data analysis for refractive surgery.

Importance of Preoperative Assessment in Refractive Surgery

In order to obtain optimal results, patients who are candidates for refractive surgery must undergo a meticulous preoperative evaluation. This makes it possible to select eligible patients and to exclude patients with risk factors [4]. In this way, it is possible to offer the patient the best surgical strategy for his condition. Clinical evidence shows that careful preoperative evaluation significantly reduces the risk of complications and improves long-term visual outcomes.

Comparing LASIK, PRK, and SMILE

Several preoperative data can guide the choice between LASIK, PRK and SMILE. Studies comparing these techniques have shown that SMILE offers advantages in terms of tissue preservation, particularly for patients with high myopia [2–5]. PRK should be preferred for patients with thinner corneas or those who have a high risk of ectasia. In clinical practice, the decision to opt for one procedure over another is often influenced by preoperative measurements of corneal thickness, curvature, and the presence of higher-order aberrations [6]. The most popular choice for patients with moderate to high myopia and sufficient corneal thickness is the LASIK technique [7]. However, in patients where tissue preservation is a priority, the SMILE technique has emerged as a viable alternative due to its minimal impact on corneal structure. It is also possible to opt for PRK in patients with thin corneas, as it avoids the creation of a flap and therefore reduces the risk of flap-related complications [8]. The subtle differences in patient appropriateness, corneal thickness requirements, and risk factors for each procedure must be taken into account while assessing LASIK, PRK, and SMILE as main refractive surgical methods. Because treatment requires making a corneal flap to reach deeper layers, LASIK is frequently used for patients with moderate to high myopia who have adequate corneal thickness. LASIK is quite popular because of this flap generation process, which enables quick vision recovery and little postoperative discomfort. To guarantee postoperative safety, LASIK necessitates a minimum corneal thickness because excessive corneal tissue removal raises the possibility of ectasia. Because these problems can increase the risk of structural instability after surgery, LASIK is generally contraindicated in individuals with thinner corneas or those with uneven topographic patterns. Although improvements in tailored ablation profiles have decreased the dangers, patients with big pupils may still experience night vision problems such glare and halos. In contrast, PRK eliminates the corneal epithelium, directly modifying the surface layer, without the need to create flaps. Because PRK maintains more corneal tissue, it is therefore more appropriate for individuals with thinner corneas or those who already have ectasia risk factors. PRK has a longer recovery period than LASIK, and patients usually have more postoperative discomfort and delayed visual stabilization, despite the benefits in structural preservation. However, PRK is a better choice for patients with uneven corneal topographies or lower corneal thickness thresholds since it carries a lesser risk of flap formation problems including dry eye syndrome or flap dislocation. Patients who are prone to activities like contact sports that could otherwise disrupt a LASIK flap may also benefit from PRK's surface-level ablation. A more recent development, SMILE, removes a lenticule by making a tiny incision in order to reduce corneal impact. Because SMILE doesn't involve a huge flap like LASIK and PRK do, it significantly lessens the symptoms of dry eyes while maintaining corneal biomechanics. Because SMILE preserves corneal strength better than LASIK, it is especially beneficial for patients with excessive myopia. SMILE is currently limited in its ability to treat astigmatism, and patients with uneven corneal topographies or extremely thin corneas are generally not advised to use it. PRK is still frequently the recommended option for patients with limited corneal thickness, however SMILE is a great substitute for those who value biomechanical preservation with the right corneal thickness.

In conclusion, each procedure—LASIK, PRK, and SMILE—has particular advantages and disadvantages. Individual corneal features, thickness, and risk factors have a major role in the procedure selection. PRK is best for people with thinner corneas or high-risk profiles for ectasia, SMILE is best for people who need myopia correction with the least amount of biomechanical impact, and LASIK is best for people who want a quick recovery with sufficient corneal thickness. Refractive surgeons can lower postoperative risks and increase patient satisfaction by tailoring their surgical approach to these variables.

Prevention of Complications

One of the most feared complications in refractive surgery, and in particular in the LASIK technique, is corneal ectasia, a progressive thinning and exhaustion of the cornea. This condition often occurs when patients with thin corneas or abnormal curvature are operated on without adequate preoperative recognition. In particular, corneal topography is a tool used to identify early signs of keratoconus or other corneal irregularities that could predispose patients to corneal ectasia after surgery [9]. Topographic maps are essential as they allow to recognize and exclude candidates at high risk of developing complications after LASIK [9]. For example, patients with topographic maps indicative of asymmetrical bowtie astigmatism or lower steepening are often considered unsuitable for LASIK; these patients may be offered alternative, safer procedures such as PRK or implantable collamer lenses (ICLs) [10]. Pachymetry, the measurement of corneal thickness, is essential to estimate whether enough tissue will remain after corneal remodeling. In clinical practice, it is generally appropriate to leave a residual stromal bed of at least 250 microns; this avoids any destabilization of the cornea [10]. Therefore, patients with corneal thicknesses below this threshold are generally not considered candidates for LASIK. American Academy of Ophthalmology (AAO) guidelines recommend a minimum residual stromal bed of 250 microns after LASIK to prevent the development of post-surgical ectasia [2]. Complications, including dry eye syndrome, halos, and glare, can profoundly affect the postoperative quality of life. Executing a thorough preoperative evaluation that encompasses patient history, topographic mapping, and aberrometry might reduce these risks by customizing treatment to lessen unpleasant effects.

Predicting Visual Outcomes

Preoperative assessment not only minimizes the risk of complications but also serves as an important tool for predicting postoperative outcomes. In practice, preoperative data are used to establish real expectations for patients, particularly in patients with high myopia or astigmatism, who may be at risk of under- or over-correction [11]. For example, patients who have thin corneas and high levels of myopia should be advised that they have a higher risk of a refractive residue after LASIK. In these cases, it is important to recommend different refractive procedures such as PRK, SMILE, or ICL to the patient [10]. In fact, these procedures, by removing less corneal tissue or not removing any at all, present a reduced risk of post-surgical corneal ectasia [11]. In addition, patients with large pupils should be clearly aware of the increased risk of postoperative glare and halos, especially in low-light conditions. Pupil size measurements, combined with topography, help adjust the ablation zone to mitigate these visual disturbances [12].

Personalization of Treatment

One of the main advances in refractive surgery is the ability to personalize treatment according to the characteristics of the individual patient. In instances of high myopia or significant astigmatism, variations in accommodation measurement are essential for identifying appropriate treatments. Modifying surgical techniques according to these variations facilitates improved result predictability, particularly in patients susceptible to refractive errors. Wavefront aberromemetry plays a crucial role in this personalization of treatment. Aberrometry allows you to map higher-order aberrations (HOAs), which are responsible for visual distortions that cannot be corrected by temple lenses or contact lenses [13]. By preoperatively identifying specific HOAs, such as coma or clover, it is possible to offer the patient treatments such as wavefront-guided LASIK, which allows a personalized procedure designed to correct both high-order and low-order aberrations [14]. In clinical practice, aberrometry is increasingly becoming an important examination in the evaluation of patients who wish to undergo LASIK or PRK. Some studies have shown that patients with HOA, after undergoing LASIK treatment guided by the shame front, have improved contrast sensitivity and an improvement in the quality of night vision in the postoperative period. It is generally more suitable to choose topography-guided LASIK treatment for patients who have irregular astigmatism or other irregularities of the corneal surface [15].

Table 1. Comparison of pentacam and orbscan.

Technology	Data provided	Advantages	Limitations
Pentacam	Anterior/posterior corneal mapping, corneal thickness	High accuracy in detecting keratoconus, 3D imaging	Can struggle with corneal scarring from previous surgeries
Orbscan	Corneal thickness, anterior corneal curvature	Thickness mapping combined with topography	Less sensitive to posterior corneal changes

Identifying Non-Candidates

A complete preoperative evaluation is essential to try to identify patients who are not candidates for refractive surgery. Certain conditions, such as keratoconus, very often identified through topographic examination, or Fuchs' endothelial dystrophy, diagnosed by specular microscopy, can make patients unsuitable for laser refractive surgery procedures [16]. These patients may benefit from other approaches, which would allow them to free themselves from temple lenses or contact lenses such as ICL or refractive lens replacement (RLE) [17]. In clinical practice, patients who present with subclinical keratoconus, even if asymptomatic, and found only on preoperative examination are generally excluded from LASIK procedures [15]. Patients should be advised to undergo crosslinking procedures to stabilize the corneal scaffolding and possibly recommend treatment with corrective lenses.

Preoperative Tools in Refractive Surgery

Corneal Topography

Corneal topography allows you to create a 3D map of the corneal surface, identifying any irregularities in curvature and/or shape. Topography is a fundamental examination that allows to demonstrate the possible presence of a subclinical keratoconus and/or other asymmetries that could affect surgical results [16]. In a study of 500 patients who were candidates for LASIK, Pentacam was able to identify 8% of patients with early signs of subclinical keratoconus that would otherwise not have been recognized with standard slit-lamp examination [18]. This allows to demonstrate the fundamental role of topography in excluding high-risk candidate patients. The Pentacam is often compared to Orbscan (Table 1), which also provides thickness measurements in addition to topographic mapping. A clinical comparison of 100 patients undergoing topography with both systems found that Pentacam's accuracy in detecting posterior corneal abnormalities was superior, identifying 5% more cases of subclinical keratoconus [18]. Although Pentacam is a highly accurate tool, it has been shown that it is difficult to form topographic maps in patients who have previously undergone corneal refractive surgery, creating distorted topographic maps. In these cases, the combination of topography with optical coherence tomography (OCT)-based imaging of the anterior segment allows for more complete information on the corneal morphology of these patients [19]. Corneal topography can also be affected by external factors such as poor corneal hydration and dry eye conditions, leading to inaccurate measurements. In patients with dry eye, it is essential to treat this condition first and then repeat the measurement [20]. Corneal topography data is often crucial in deciding whether to perform a LASIK or PRK procedure. Patients with thin corneas or abnormal topographic patterns (e.g., subclinical keratoconus) may benefit from PRK or SMILE techniques, thereby reducing the risk of complications such as corneal ectasia [21]. According to European Society of Cataract and Refractive Surgeons (ESCRS) guidelines, patients undergoing LASIK should have both anterior and posterior corneal surface mapping. The guidelines emphasize that evaluation of the posterior corneal surface is critical to identify early-stage keratoconus, particularly in young myopic patients.

Pachymetry

Corneal pachymetry allows the corneal thickness to be measured; this parameter is critical to determining whether the cornea has enough tissue to be able to undergo LASIK or PRK in extreme safety. In a large-scale study of 1000 patients undergoing LASIK, OCT-based pachymetry identified 12% more cases of thin corneas ($<$500 microns) than ultrasound pachymetry, leading to changes in surgical strategies in 8% of those patients [22]. While OCT-based pachymetry allows for non-contact measurements and higher resolution, ultrasonic pachymetry remains the gold standard for accuracy [22]; especially in cases where the important irregularities of the corneal surface could distort the measurements made with OCT of the anterior segment [23]. In a clinical comparison, ultrasound pachymetry showed a 98% accuracy rate in detecting the risk of ectasia compared to 95% for anterior segment OCT [24]. OCT-based pachymetry, although easier to use for the patient due to its non-invasive nature, can produce errors in patients with severe superficial irregularities or corneal scarring, while ultrasound pachymetry is able to provide more reliable data [25]. According to AAO guidelines, pachymetry should be used in conjunction with topography to ensure that the patient has a residual stromal bed of at least 250 microns post-LASIK to minimize the risk of ectasia [2].

Wavefront Aberrometry

Wavefront aberrometry allows the measurement of higher-order aberrations (HOAs); Recognition of Dali aberrations is critical to address any visual disturbances such as glare, halos, and reduced contrast sensitivity [26]. A randomized controlled trial (RCT) of 250 patients showed that patients treated with wavefront-guided LASIK had a 35% greater improvement in night vision than those treated with conventional LASIK [27]. The ability of aberrometry to highlight and correct HOAs allows for a more precise treatment of these conditions which has made it possible to significantly reduce postoperative complications. The Zywave aberrometer and the iDesign system are the two most commonly used devices [26]. The iDesign system, in particular, has proven effective in capturing 25% more HOA than Zywave, particularly in patients with very irregular corneas. However, aberrometry can sometimes struggle with extreme corneal irregularities or previous corneal surgeries, where the optical path is disrupted. In these cases, combining aberrometry with topography allows for better and more reliable results [28]. The AAO recommends wavefront aberrometry as the preferred method for patients with significant HOA or those with a history of night vision disturbances [2].

OCT

Optical coherence tomography (OCT) is capable of providing high-resolution cross-sectional images of the cornea and anterior segment; This tool then allows for detailed visualization of the epithelium, stroma and deeper corneal layers. In a cohort of about 300 patients, OCT allowed the detection of the first signs of Fuchs' endothelial dystrophy in 4% of patients, preventing these patients from undergoing LASIK procedures [29]; These patients were then referred to different refractive surgical procedures. Spectral domain OCT (SD-OCT) is also considered the gold standard for corneal imaging, as it is capable of providing high-resolution, real-time images that allow for careful and precise surgical planning [30]. A comparative study of 150 patients showed that SD-OCT was able to detect corneal thinning with a sensitivity of 98%, compared to 94% with time-domain OCT. However, OCT can sometimes be less effective in patients who have deep corneal scarring; in this case the light signal is interrupted, leading to less clear and reliable images. In these cases, other corneal imaging techniques such as specular microscopy may be useful. The ESCRS suggests that all patients with suspected corneal endothelial disease undergo OCT imaging prior to refractive surgery [2].

Customized LASIK Preoperative Evaluation

To guarantee the best results, LASIK, one of the most popular refractive operations, needs a thorough preoperative evaluation. Since a corneal flap is created during the process, it is essential to assess factors such corneal thickness, curvature, and biomechanical stability. In order to determine whether a patient's corneal thickness is suitable for creating a flap and whether the residual stromal bed will remain after surgery, a customized preoperative evaluation for LASIK usually consists of high-resolution corneal topography and pachymetry. LASIK is not appropriate for patients with thinner corneas because they may be more susceptible to ectasia; instead, PRK or SMILE may be suggested. In LASIK preoperative planning, wavefront aberrometry is also essential because it enables surgeons to map and correct higher-order aberrations (HOAs). By lowering postoperative symptoms including glare and halos, tailoring the LASIK ablation profile according to HOAs enhances visual results. Therefore, in order to improve patient results and lower the risk of side effects, LASIK depends on precise, customized preoperative assessments that take into account both structural and optical quality.

PRK Customized Preoperative Evaluation

PRK is different from LASIK in that it removes the corneal epithelium and then reshapes the surface instead of making a corneal flap. Therefore, individuals with thinner corneas or those with topographic anomalies that may make them more susceptible to flap-related issues in LASIK are better candidates for PRK. A detailed examination of corneal topography and thickness is part of the customized preoperative strategy for PRK since these variables affect the rate of epithelial healing and the possibility of haze formation. Topography-guided ablation, which smoothes the corneal surface and treats irregular astigmatism, can be used to optimize PRK for patients with irregular corneal surfaces. In order to determine how much tissue can be safely removed to achieve the necessary refractive correction while lowering the danger of corneal haze or ectasia, pychmetry is also crucial. Furthermore, wavefront-optimized PRK, which addresses aberrations specific to each patient's optical profile, is made possible by the use of aberrometry in PRK to tailor treatment for patients with HOAs. This customized strategy guarantees that PRK produces safe and efficient outcomes, even for people who might not be good candidates for LASIK.

Customized SMILE Preoperative Evaluation

SMILE offers a distinct set of benefits as a minimally invasive procedure for patients who need a more cautious approach to corneal reshaping. The lack of a substantial surface ablation or flap development in SMILE, in contrast to LASIK and PRK, lowers the risk of dry eye complaints and preserves more of the cornea's biomechanical integrity. Since SMILE is particularly helpful for patients with high myopia and adequate corneal thickness who might not be able to endure the tissue removal necessary for LASIK, the personalized preoperative evaluation for this procedure is focused on assessing corneal thickness, curvature, and biomechanical strength. In order to identify abnormalities like subclinical keratoconus that may make SMILE contraindicated due to the risk of postoperative ectasia, corneal tomography—which measures both anterior and posterior corneal curvature—is essential. A thorough examination of the patient's refractive error is required to ascertain whether their astigmatic correction requirements surpass SMILE's

Table 2. Comparison of wavefront-guided and topography-guided LASIK.

Parameter	Wavefront-guided LASIK	Topography-guided LASIK
Higher-order aberrations (HOAs)	Corrects HOAs such as coma, trefoil, and spherical aberration. Significant reduction in night vision disturbances (30% improvement in contrast sensitivity).	Primarily focuses on corneal surface irregularities; not as effective in correcting HOAs.
Postoperative glare and halos	25% reduction in glare and halos.	Less reduction in glare and halos compared to wavefront.
Irregular corneas	Less effective for irregular corneas due to the focus on optical path aberrations.	Superior in treating irregular astigmatism or mild keratoconus by customizing corneal reshaping.
Uncorrected distance visual acuity (UDVA)	Improvement in visual quality in cases of high aberrations, especially in low-light conditions.	Better improvement in UDVA for patients with irregular astigmatism.
Refractive stability (10 years)	5% refractive regression over 10 years.	Similar stability with low risk of regression over long-term follow-up.
Best indications	Ideal for patients with high-order aberrations, night vision issues, or glare.	Best for patients with irregular corneal shapes, keratoconus, or astigmatism.

LASIK, Laser-Assisted *In Situ* Keratomileusis.

capacity, given that SMILE is less successful in correcting astigmatism. Patients may be referred to PRK or LASIK as alternate therapies in these situations. Therefore, individualized preoperative evaluation optimizes the safety and effectiveness of this surgery by concentrating on the distinctive features of SMILE and choosing patients appropriately.

Connecting the Selection of Surgical Technique with Preoperative Parameters

An integrated approach to preoperative data, which takes into account not only the physical measures of each patient but also the unique advantages and disadvantages of each surgery, should serve as the basis for choosing between LASIK, PRK, or SMILE. The choice of surgery must be in line with the patient's corneal thickness, curvature, and optical quality, which vary greatly across patients, according to a personalized approach to refractive surgery. For example, patients with large pupils and high myopia might benefit from the minimally invasive SMILE technique, which maintains corneal strength, whereas individuals with HOAs might benefit more from wavefront-guided LASIK (Table 2). Similarly, PRK might be a safer option for patients who are at risk for ectasia because of uneven topography or borderline corneal thickness. By incorporating these factors into a patient-centered selection process, the surgical approach is matched with each patient's unique risk profile and aesthetic objectives, guaranteeing that each patient gets the operation that best strikes a balance between safety and efficacy. By applying the knowledge gained from preoperative evaluations, this strategy goes beyond a one-size-fits-all approach to increase surgical accuracy and long-term patient satisfaction.

Discussion

One of the most significant contributions of preoperative tools has been to try to prevent postoperative corneal ectasia. Corneal topography and pachymetry play a critical role in identifying patients who are at high risk before surgery. In a 10-year clinical trial, patients who were excluded from LASIK due to abnormal topographic findings or thin corneas had a markedly reduced incidence of ectasia, reinforcing the need for thorough preoperative screening [31]. For example, a 28-year-old man with borderline pachymetry (490 microns) and mild posterior elevation detected on Pentacam was advised to undergo PRK instead of LASIK. After surgery, the patient achieved a vision of 20/20 without ectasia, which demonstrates the importance of using topography and pachymetry to tailor surgical approaches according to individual risk [31]. To reduce the incidence of postoperative ectasia, the American Academy of Ophthalmology advises LASIK candidates to have a minimum residual stromal bed of at least 250 microns, especially in patients with thinner corneas or high myopia (AAO Refractive Surgery Preferred Practice Pattern, 2018). In order to identify early indicators of keratoconus, especially in young myopic patients who may be more susceptible to problems, the ESCRS recommends a comprehensive preoperative corneal assessment that includes both anterior and posterior corneal mapping. In order to enhance visual results and reduce postoperative problems like glare and halos, both organizations also advise patients with severe higher-order aberrations to use wavefront aberrometry and topography-guided LASIK [32]. This study emphasizes the significance of evidence-based preoperative evaluations to improve patient selection, lower risks, and maximize postoperative outcomes in refractive surgery by following these authoritative guidelines. In cases where corneal thickness is at its limit, switching to superficial ablation techniques such as PRK or SMILE ensures both safety and efficacy [32]. Preoperative tools such as topography-guided LASIK have revolutionized and transformed the ability to correct complex irregular astigmatism [33]. From a clinical point of view, corneal topography in particular allows laser ablation to be customized and adapted to the patient, which is a particularly important factor in patients with irregular corneas. A study of 300 patients with irregular astigmatism showed that those treated with topography-guided LASIK achieved significantly better uncorrected distance visual acuity (UDVA); patients also developed fewer postoperative complications than conventional LASIK [34]. In clinical practice, this approach has been especially valuable for patients with asymmetrical corneal curvatures or mild keratoconus [33]. In one case, a 42-year-old woman who had mild marginal pellucida degeneration underwent topography-guided LASIK, which targeted the area of corneal thinning. After surgery, the patient achieved a vision of 20/25 with a marked improvement in visual quality and stability over a 3-year follow-up period [35]. Long-term stability is a fundamental condition for evaluating the real success of refractive surgery. Several clinical trials have shown that patients undergoing wavefront-guided LASIK and topography-guided LASIK maintained stable visual outcomes for up to 10 years, with minimal refractive regression [35]. A meta-analysis of 2000 patients who underwent LASIK surgery confirmed that those treated with wavefront-guided LASIK had 32% fewer cases of refractive regression than patients who underwent conventional LASIK treatment [36]. As you can easily guess, this evidence suggests that ablation profiles tailored to the individual patient are more effective in maintaining long-term visual stability [37]. For example, in a 10-year follow-up study of 200 patients with high myopia, only 5% had significant refractive regression. Predictive models based on the combination of different preoperative examinations such as topography, pachymetry and aberrometry make it possible to effectively predict long-term results, thus minimizing the need for improvement procedures [38]. The integration of machine learning and artificial intelligence (AI)-based predictive models into refractive surgery has become an increasingly valuable and critical tool for trying to minimize postoperative complications and improve outcomes [39]. AI-based predictive models that analyze and stitch together different parameters are capable of predicting postoperative corneal ectasia with an accuracy rate of 85% [39]. Clinically, these models were implemented to stratify patients according to their risk profiles. For example, a 40-year-old woman with borderline pachymetry and subtle topographic irregularities was reported by the predictive model as being at high risk of developing ectasia. The patient was therefore recommended to have surgery with the PRK technique; This significantly reduced the risk of postoperative complications.

Personalized preoperative planning facilitates risk classification, which is essential for patient safety in addition to the technical customisation of refractive operations. For example, surgeons can better predict hazards such postoperative ectasia, under-correction, or glare by examining variables like corneal thickness, pupil size, and myopic degree, particularly in patients with big pupils or extreme myopia. The significance of corneal thickness in preoperative evaluations is highlighted by the American Academy of Ophthalmology (AAO) standards, which suggest a residual stromal bed thickness of at least 250 microns after LASIK. Instead of LASIK, patients with borderline thicknesses might be recommended PRK or SMILE because these procedures either do not create flaps or have a smaller corneal impact, maintaining corneal stability. The hallmark of customized refractive surgery planning is the ability to choose the safest and most efficient operation for each patient, which helps to improve long-term visual stability and minimize negative effects.

By incorporating predictive analytics into the preoperative workflow, recent developments in artificial intelligence (AI) have improved individualized preoperative planning even further. A wide range of patient-specific factors, including corneal thickness, shape, and visual history, can be analyzed by AI-driven models to predict the likelihood of problems and the chance of obtaining the intended postoperative outcomes [39]. AI-based predictive models, for instance, have demonstrated encouraging accuracy in identifying patients who are at high risk for postoperative ectasia. This enables surgeons to adjust their strategy or suggest different procedures for these patients. AI gives surgeons the ability to make data-driven decisions that beyond conventional diagnostic methods by offering probabilistic risk evaluations, which enhances the accuracy of individualized planning. AI substantially enhances refractive surgery through improved predictive accuracy and refined preoperative evaluations. AI-driven algorithms may analyze extensive datasets to identify patients at risk of problems like ectasia, facilitating tailored surgical planning. These models enable accurate modifications to surgical methods, such as adjusting ablation zones according to individual corneal topographies, hence minimizing the incidence of postoperative problems. Patients are better able to grasp the risks and possible results based on their individual profiles thanks to this predictive method, which also makes it possible to choose surgical techniques more precisely.

In general, the ability of customized preoperative design to lower problems, enhance patient happiness, and improve visual outcomes makes it significant in refractive surgery. Surgeons can reduce postoperative problems and guarantee long-lasting visual gains by matching surgical approaches to the unique characteristics of each patient. This method puts patient safety and outcome prediction at the forefront of refractive surgery, moving away from one-size-fits-all approaches and toward a data-driven, patient-specific approach. Personalized preoperative design will probably become the norm in refractive care as diagnostic and predictive technology developments continue to advance. This will change the way doctors treat vision correction and guarantee that every patient gets the best, safest, and most efficient treatment possible.

Future Perspectives in Refractive Surgery

The field of refractive surgery, in the wake of amazing technological advances, is rapidly evolving. Several key developments are poised to shape the future of refractive surgery, improving accuracy, safety, and postoperative and long-term outcomes for patients. Artificial intelligence (AI) and Machine Learning Artificial intelligence and machine learning (ML) are becoming more and more present in our clinical practice and are finding more and more space in refractive surgery [40]. AI-based predictive models are already showing promise in accurately predicting possible postoperative complications in the individual patient. These systems can allow for a careful risk assessment for each patient, helping surgeons make more informed decisions about surgical candidacy and the best procedural approach. In addition to preoperative planning, AI is also expected to play a significant role in intraoperative driving. Artificial intelligence systems capable of analyzing surgical data in real time will be able to offer intraoperative adjustments and adjustments, allowing the surgical procedure to be modified based on real-time feedback received from imaging tools such as OCT or intraoperative aberrometry [40]. This integration could further improve accuracy and minimize the need for postoperative improvements. The use of real-time intraoperative imaging technologies is increasing in surgical practice. Tools such as intraoperative OCT and intraoperative corneal topography are already widely used to provide real-time data during surgery, thus allowing for any immediate adjustment based on the patient's unique corneal anatomy. These intraoperative techniques allow for a high level of accuracy, which is critical for ensuring accurate laser alignment during procedures such as topography-guided LASIK or SMILE [39]. In addition, the development of AI-assisted intraoperative imaging could lead to the development of more autonomous adjustments, in response to unpredictable intraoperative data, thus improving safety in complex cases. The use of these technologies could therefore reduce the risk of complications resulting from flap creation or thinning of the cornea, ultimately improving overall results. The use of femtosecond laser technology in clinical practice has already made it possible to transform the field of refractive surgery, in particular thanks to procedures such as Femto-LASIK and SMILE. These new generation lasers guarantee unparalleled precision in the creation of the corneal flap; This allows for safer surgeries with a lower risk of complications. Future advances in femtosecond laser technology should include real-time laser adjustments based on corneal feedback obtained during surgery; this would further reduce the risks associated with traditional LASIK procedures. In addition, more and more clinical evidence indicates that small-incision lenticule extraction (SMILE) is a promising alternative to LASIK, especially for patients suffering from dry eye or those who have a high risk of corneal flap-related complications. Continued refinements of the SMILE technology are likely to expand its use in more complex refractive cases, thus offering patients and surgeons a minimally invasive alternative with faster recovery times. The new corneal imaging systems allow for more detailed corneal analysis, from mapping epithelial thickness and status to assessing biomechanical properties. Tools such as Scheimpflug tomography and optical coherence elastography (OCE) allow you to obtain a precise measurement of corneal stiffness and elasticity, thus offering useful information on the structural integrity of the cornea [41]. The routine use of these techniques would allow to obtain further useful data that would increase the levels of safety in the preoperative screening of keratoconus and in the evaluation of patients with borderline thicknesses who are candidates for refractive surgery [42]. By assessing the biomechanical response of the cornea, it is possible to analyze and predict how the cornea will react to ablation, reducing the likelihood of complications such as ectasia.

The integration of genomic data into refractive surgery is an emerging field not yet used in practice that could have significant potential for personalized medicine. By analyzing a patient's individual genetic predisposition to pathological conditions such as keratoconus or corneal dystrophies, it would be possible to personalize surgical treatments even more precisely. For example, if a patient were identified as genetically predisposed to developing keratoconus, they could be flagged as being at high risk of developing post-LASIK complications and referred accordingly to safer surgical alternatives such as PRK or corneal cross-linking [43]. This personalized approach will allow to go beyond the anatomical data provided by tools such as topography and pachymetry, integrating genetic information so as to refine the surgical strategy. The use of these emerging technologies in clinical practice would allow the selection of the most appropriate procedure based not only on the patient's corneal structure, but also on his genetic risk factors, this would minimize the likelihood of complications and improve long-term stability. In the near future, refractive surgery could reach a level of total personalization, where a patient's surgical plan is entirely adapted from preoperative diagnostics to postoperative care based on a combination of genomic data, biomechanical properties, and anatomical characteristics. This would involve not only choosing the appropriate surgical technique but also adjusting laser settings, flap size, and postoperative care protocols to match the individual's unique profile. For example, in the case of a patient with a proven genetic predisposition to corneal thinning, he or she could be directed towards less invasive options such as superficial ablation techniques (e.g., PRK) or combined with corneal cross-linking to prevent the development of future ectasia [43]. Similarly, patients with a low risk of complications and favorable genomic markers could undergo femtosecond LASIK procedure with optimized laser ablation models. This level of personalization has the potential to transform refractive surgery into a truly personalized treatment, reducing postoperative complications, improving patient satisfaction, and delivering more predictable outcomes.

Conclusions

A variety of innovative pre-operative instruments is becoming the norm in refractive surgery. Clinical results have been transformed by these technologies. Corneal topography, pachymetry, and wavefront aberrometry allow clinicians to customize examinations. It improves patient selection and procedure customization. Personalized preoperative planning lowers corneal ectasia and enhances visual quality and long-term stability by tailoring operations to each patient's anatomy and function. The expanding use of artificial intelligence in preoperative evaluations may make refractive surgery more data-driven and accurate. This has the potential to improve patient selection and result prediction. This customized approach maximizes safety and efficacy by tailoring treatment strategies to each patient. AI-driven models have improved refractive surgery predicting accuracy, allowing physicians to pick patients and tailor operations to risk profiles strategically. This idea could improve surgical outcomes and postoperative complications. AI predictions and clinical evaluations could personalize refractive procedures and transform customized care. In clinical practice, detailed, tailored preoperative screening helps surgeons enhance patient outcomes and reduce side effects. Refractive surgery will likely become more customized as technology and predictive tools improve, leading to safer operations and improved patient satisfaction. Refractive surgeons who seek reliable, long-lasting results must prioritize preoperative analysis and accept new innovations. Refractive surgery has a promising future. Genomic technology, real-time intraoperative changes, and predictive data analytics are transforming surgeries from "just" individualized to fully personalized based on each patient's unique profile. The future of refractive surgery depends on preoperative data, accurate analysis, and patient success.

Availability of Data and Materials

Not applicable.

Author Contributions

Conceptualization, FV, CG, MZ; methodology, FV, CG, FD, MM, DT, MZ; validation, FV, CG, FD, MM, DT, MZ; formal analysis, FV, CG; investigation, FV, CG; resources, CG, DT, MZ; writing—original draft preparation, FV, CG; writing—review and editing, FV, CG, FD, MM, DT, MZ; visualization, FV, CG, FD, MM, DT, MZ; supervision, CG, DT, MZ. All authors have been involved in revising it critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

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