COMPARING THE OUTCOMES OF DIFFERENT CORNEAL REFRACTIVE SURGERIES, SUCH AS LASIK (LASER ASSISTED IN SITU KERATOMILEUSIS), PRK (PHOTOREFRACTIVE KERATECTOMY), AND SMILE (SMALL INCISION LENTICULE EXTRACTION)

Abstract

This literature review provides an in-depth analysis of visual outcomes, dry eye incidence, corneal sensitivity, and high-order aberrations (HOAs) associated with three common corneal refractive surgeries: Transepithelial Photorefractive Keratectomy (Trans-PRK), Laser-Assisted in Situ Keratomileusis (LASIK), and Small Incision Lenticule Extraction (SMILE).In terms of visual outcomes, Trans-PRK demonstrates favorable efficacy and safety comparable to LASIK, with potential advantages in predictability. However, Trans-PRK adult patients may experience higher variability in spherical equivalent during the postoperative period. Conversely, SMILE exhibits comparable visual outcomes to LASIK, but with delayed visual acuity recovery possibly due to stromal edema. Comparative studies between Trans-PRK and SMILE are limited, but initial findings suggest SMILE may offer improved visual results and reduced residual astigmatism.Dry eye and corneal sensitivity post-surgery vary among procedures, influenced by factors such as nerve damage, flap size, and ablation size. PRK results in severance of corneal nerves, leading to temporary postoperative pain, whereas LASIK and SMILE show differing rates of reinnervation, with SMILE potentially preserving corneal sensitivity better due to its less invasive nature.High-order aberrations, affecting visual quality, differ among surgeries. Trans-PRK is believed to induce fewer aberrations due to greater corneal integrity compared to LASIK, while SMILE may lead to higher levels of coma and total HOAs in the early postoperative period.

Keywords: Visual Outcomes, Eye Surgeries, Small Incision Lenticule Extraction, Laser-Assisted in Situ Keratomileusis, Transepithelial Photorefractive Keratectomy

Introduction

The field of corneal refractive surgeries is advancing into an era dominated by all-laser procedures. Two prominent techniques leading this shift are Single-Step PRK and SMILE(1).

These procedures use femtosecond lasers for SMILE and excimer lasers for tPRK, marking a significant advancement in safety and accuracy(1).

PRK obtained the inaugural approval as a refractive surgical procedure by the U.S. Food and Drug Administration in 1996(2). PRK, representing surface refractive surgery, stands as a novel procedure that removes both the stroma and epithelium simultaneously(3). By foregoing flap creation or corneal incisions, tPRKhas proven to be successfully decreasing both operative time and postoperative corneal biomechanical alterations(4). However, the major drawback of this surgery is postoperative pain(4).

Following the introduction of PRK, laser-assisted in situ keratomileusis emerged and gained FDA approval in 1998, swiftly superseding PRK as the primary refractive surgery method globally since the 1990s(5). In LASIK procedures, a lamellar corneal flap is crafted using a mechanical microkeratome(6). Subsequently, the flap is raised, allowing for excimer laser ablation on the underlying stromal bed(7). Once the ablation is complete, the corneal flap is repositioned onto the corneal surface(7).

Likewise, SMILE has gained significant traction as a leading example of lamellar refractive surgery. Unlike procedures such as femtosecond laser-assisted in situ keratomileusis (FS-LASIK), SMILE involves removing the corneal lenticule from the mid-stroma without creating a flap. This approach minimizes disruption to anterior corneal surface and corneal nerve branches, resulting in a reduced risk of dry eye and better preservation of corneal sensitivity(8).

As mentioned above, SMILE and LASEK stand as cutting-edge advancements in surface and lamellar refractive surgeries. While numerous studies have affirmed the safety and efficacy of both SMILE and LASEK, SMILE exhibits a lower incidence of inducing higher-order aberrations compared to LASEK(9, 10). In another two studies SMILE procedure revealed a lower risk of HAOS, refraction, and visual acuity in comparison with tPRK(11, 12). In another study, in comparison to LASEK and PRK, PRK showed promise in terms of fast epithelial healing, diminished discomfort, and reduced levels of haze(4).

This study aims to provide a thorough comparison of clinical outcomes (i.e. visual acuity, dry eye corneal sensitivity, and high-order abrasions), between SMILE, LASEK, and PRK.

2. Literature Review

2.1 Visual Outcomes (Safety, Efficacy, and Predictability)

The visual outcomes include predictability, efficacy, and safety. Efficacyis defined as achieving uncorrected distance visual acuity (UDVA) of 20/20 or better. Safety is characterized by not losing one or more lines of best-corrected visual acuity, across the three surgical approaches mentioned above. While the predictability of refraction refers to the accuracy in estimating the change in postoperative mean spherical equivalent (SE).

2.1.1 Trans-PRK vs LASIK

Data is limited regarding the visual outcomes of Trans-PRK and LASIK. Several investigations on the high myopic and myopic patients group demonstrated the satisfactory or similar safety and efficacy of Trans-PRK(13-15). According to two studies, under-correction of eyes occurredin FS-LASIK and overcorrection of eyes occurredin Trans-PRK, which may explain the Trans-PRK group's higher UDVA(15, 16). Regarding predictability, in two studies, for both the high myopic and myopic groups of Trans-PRK patients, the refraction predictability and target refraction percentage were ± 0.5 diopters (D) in the 12-month follow-up were better or equivalent(15, 16). Mounir et al, in contrast, discovered that FS-LASIK groups allocated to high myopic Egyptians had improved predictability(13). During the six months following surgery, Trans-PRK groups showed higher variability in SE, which may be related to the ongoing epithelial healing process(13, 16). Additionally, compared to those treated with LASIK (0.38%–16%), myopic individuals treated with traditional PRK had retreatment rates ranging from 3.8% to 20.8%(17, 18). Retreatment rates were associated with age over 40, flap thickness, small optical zone, unstable fixation Adjuvant mitomycin-C, and high correction in PRK and LASIK groups (17). Retreatment rates generally decreased, most likely as a result of better technology and more experienced surgeons(18).

2.1.2 LASIK vs. Smile

In both long-term(19, 20) and short-term(21-23)investigations, the visual outcomes of SMILE and FS-LASIK werecomparable. Additionally, the same results were obtained in the high myopic group which either received FS-LASIK orSMILE.On the first day after surgery, the UDVA showed improvement in the FS-LASIK group, but the mean SE was considerably higher in the SMILE group (24). Additionally, the SMILE group experienced a delay in the recovery of visual acuity compared to the FS-LASIK patients(24). At postoperative days 7 and 1, contrast sensitivity was superior in the FS-LASIK group; however, at 1 month, there was no discernible difference. On day seven, participants in the SMILE group reported much lower eyesight quality(25). The delayed recovery of visual acuity following SMILE may be due to stromal edema occurring from lenticular manipulation(26).

2.1.3 Trans-PRK vs SMILE

There weren't many articles contrasting the outcomes of SMILE and PRK. One study showed that a month after surgery, SMILE showed improved visual results and less residual astigmatism(27). However, at the 3- and 6-month follow-ups, these parameters started to resemble one another between the groups(12).

2.2 Dry Eye and Corneal Sensitivity

Dry eye commonly occurs after refractive surgeries due to decreased corneal nerve density. The patterns of nerve damage and recovery differ among SMILE, LASIK, and PRK procedures.

2.2.1 PRK

In PRK, photoablations result in the severance of the anterior stromal nervesand sub-basal plexus while preserving the deep stromal nerves(28). Following ablation, nerve endings become visible at the corneal surface until epithelial regrowth occurs, leading to potential postoperative pain lasting 2-10 days(29). Bandeira et al indicated that sub-basal nerve regeneration reached nearly 50 percent at six to eight months postoperatively, steadily increasing to 90 percent at the 2-year follow-up(30). CS typically recovered to 80 percent within one week postoperatively and nearly fully restored within three to six months(31). Reductions in tear break-up time and Schirmer test scores, along with increased symptom scores, were observed at 1, 3, and 6 months postoperatively in PRK(31).

2.2.2 LASIK

There aren't many studies that compare the dry eye features of PRK with LASIK. A study by Lee et al reported that at the 3-month follow-up, (29)reported lower Schirmer test and shorter longer tear break-up time were observed in LASIK compared to PRK; however, Bower et al. observed a greater reduction in the Schirmer test in PRK compared to LASIK at the postoperative 1 and 3 months(32). At the1,3, and 6-month follow-ups, the symptoms scores for both PRK and LASIK improved, and at the 12-month postoperative mark, they both went back to their baseline(31).

After LASIK, reinnervation was the slowest of the three procedures. After six months of surgery, only about 27% of the area had reinnervation; after five years, it had progressively recovered to 79%(30). However, between 6 and 16 months, corneal sensitivity nearly restored to normal, which contradicted findings from in vivo confocal microscopy research(33).

2.2.3 SMILE

Theoretically, because SMILE requires a smaller incision and allows for the excised lenticule to be chopped in a deeper plane, preserving the superficial nerves, it is less invasive than LASIK(30, 33). After one month, initial reinnervation had progressed quickly, reaching about 55%. After a week, corneal sensitivity increased to 76%, and it continued to rise progressively until six months later, albeit to a lesser level than the baseline (86%)(30, 33). At an average 4.1-year follow-up, the SMILE group had greater corneal nerve fiber density in the only long-term study that examined reinnervation between SMILE and LASIK (34). Furthermore, there was no change in the symptoms of the dry eye between incisions of 2, 3, and 4 mm, according to Cetinkaya et al(35).

2.3 High Order Abrasions

After refractive surgery, the majority of patients reach a UDVA of 1.0. However, some continue to voice concerns regarding symptoms connected to diminished visual quality caused by HOAs, including coma, poor night vision, glare, halos, and ghosting(36). The formation of flaps, tear film stability, alterations in biomechanical characteristics, and the wound-healing process all contribute to HOAs(36)

2.3.1 Trans-PRK vs LASIK

Trans-PRK is believed to have fewer aberrations than SMILE or FS-LASIK because it preserves greater corneal integrity(36). Comparing the aberrations of FS-LASIK and Trans-PRK reveals a research gap. One month after surgery, Jiang et al.found that after FS-LASIK, there was a greater rise in spherical aberrations, vertical coma, and total HOAsthan after Trans-PRK(36, 37). At the three-month follow-up, the aberrations in the patients with low to moderate myopia from both groups were comparable(36, 37). Zhang et al. (2016) discovered that after a year of surgery, the FS-LASIK group had more total HOAs and vertical comas in patients with severe myopia than the Trans-PRK group(37). According to earlier reports, a vertical coma was induced by the formation of a flap on the superior side, whereas a horizontal coma was induced by the creation of a flap on the nasal side(38).

2.3.2 LASIK vs SMILE

In a study, Wavefront aberration values between SMILE and FS-LASIK were compared, and the results showed that FS-LASIK had greater SAs after three months, six months, one year, fifty-nine months, and five yearsfollowing the procedure(39). In large pupil diameters, SAs generated more evident issues than coma. Ablation zones and the morphology of the cornea were linked with postoperative SAs(40). Less corneal morphological alterations and a larger ablation zone with SMILE may result in fewer SAs than following FS-LASIK(41, 42). Moreover, at three months, and one year after surgery, FS-LASIK had a higher total number of HOAs(43). In comparison to SMILE, FS-LASIK elicited a greater wound-healing response and inflammatory infiltration, which in turn led to a higher induction of total hypoxia(40). However, a number of studies discovered no appreciable variation in aberration levels between SMILE and FS-LASIK at three months, six months, six months, six months, one year, three years, and five years(44). The single randomized, pair-eyed trial did not find any statistically significant differences between FS-LASIK and SMILE in terms of total HOAs or visual outcomes at the 3-, 6-, or 12-month follow-up(21).

2.3.3 SMILE vs. Trans-PRK

There haven’t been many studies done comparing SMILE and Trans-PRK aberrations. According to a study, total HOAs and Coma following SMILE at postoperative 1 and 3 months were found to be considerably higher than those following Trans-PRK(45). Six months after surgery, Lee et al.discovered that the SMILE group had a greater coma but fewer overall HOAs and SAs(46). As was previously indicated, coma following SMILE may be linked to incorrect centration, whereas SAs were connected with the healing process of the wounds and the shape of the cornea (46).

Conclusion

In conclusion, each refractive surgery technique has its unique advantages and limitations. Trans-PRK appears to offer favorable visual outcomes and fewer aberrations, while LASIK and SMILE show comparable efficacy with differences in dry eye symptoms and induced aberrations. Factors such as corneal nerve damage and recovery, as well as wound healing responses, play critical roles in determining postoperative outcomes. Therefore, the selection of the most suitable surgical approach should be individualized based on patient characteristics, preferences, and risk factors, considering both short-term and long-term visual outcomes, dry eye symptoms, and induction of high-order aberrations. Further research and clinical studies are warranted to continue refining and optimizing these refractive surgery techniques.

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