ARTYKUŁ PRZEGLĄDOWY REVIEW ARTICLE

DOI: 10.24292/01.OT.250323.7

Corneal biomechanical changes after myopic and hyperopic laser vision correction

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HIGHLIGHTS

Laser refractive surgery procedures reduce the corneal biomechanical stiffness in a different way. Understanding of these biomechanical changes might improve the safety and efficacy of laser vision correction treatment planning.

ABSTRACT

Laser vision correction became a popular method of refractive error treatment. The laser vision correction techniques influence the corneal biomechanical properties including corneal hysteresis and corneal resistance factor. The ocular response analyzer and Corvis ST devices are used in clinical practice to measure the corneal biomechanics. Reasonable laser treatment planning, taking into account the impact on corneal biomechanics, may potentially improve the safety of the refractive procedures. Thicker caps in refractive lenticule extraction and thinner flaps in flap-related procedures promote better corneal biomechanics preservation. The myopic refractive treatment appears to have a greater effect on corneal biomechanics weakening than hyperopic correction.

Key words: corneal biomechanics, corneal hysteresis, corneal resistance factor, laser vision correction, myopia, hyperopia, SMILE, LASIK, PRK

INTRODUCTION

The corneal biomechanical properties define the corneal bio-elasticity, viscosity, stiffness and corneal response to applied force. The role of this parameters in laser vision correction is currently under research of numerous clinical and experimental trials. It is believed that the preoperative corneal biomechanics may influence the risk of postoperative complications such as corneal ectasia [1]. The change in biomechanical parameters after laser vision correction depends on many factors, including type and size of refractive error, type of refractive surgery procedure, flap thickness, cap thickness, residual stromal thickness. Understanding corneal biomechanics may facilitate the treatment planning, and potentially improve the safety and efficacy of the laser vision correction procedures. The ocular response analyzer (ORA) or Corvis ST provide the specific parameters of corneal biomechanics, including corneal hysteresis (CH), corneal resistance factor (CRF), first applanation time (A1T), highest concavity point (HC), stiffness parameter at the 1st applanation (SP-A1).

CORNEAL BIOMECHANICS AFTER MYOPIC LASER VISION CORRECTION

The corneal refractive surgery procedures for myopia correction include photorefractive keratectomy (PRK), laser-assisted sub-epithelial keratectomy laser (LASEK), laser in situ keratomileusis (LASIK), femtosecond LASIK (FS-LASIK), and refractive lenticule extraction (SMILE). According to the current studies, the myopic laser vision correction results in the weakening of the corneal biomechanical strength measured by ORA and Corvis ST [1–10]. The current clinical trials and meta-analyses are mostly consistent in terms of higher postoperative reduction of CH and CRF parameters after LASIK/FS-LASIK than after SMILE and PRK in patients treated for myopia and/or myopic astigmatism [5, 11–16]. Nevertheless, there are controversies in terms of Corvis ST – derived biomechanical parameters post SMILE vs. FS-LASIK [1, 5, 16]. Some studies proved significantly stronger Corvis ST biomechanical parameters after SMILE than LASIK/FS-LASIK [5, 16]. In contrast, the meta-analysis by Guo et al. revealed no significant differences in Corvis ST corneal measurements between those two procedures [1]. The authors suggested that the interpretation of postoperative biomechanics may be biased by the magnitude of refractive error corrected, percentage of tissue altered, central corneal thickness, intraocular pressure, and age of the patients [2]. The independent reports on the results of corneal biomechanics after surface treatments (PRK/LASEK) compared to LASIK/FS-LASIK are mostly similar [5, 13, 17–20]. The postoperative values of CH and CRF are higher in patients following PRK/LASEK than after LASIK/FS-LASIK [5, 13, 17–20]. In turn, the results of CH, CRF or Corvis ST biomechanical parameters, after PRK/LASIK versus SMILE, do not differ significantly [1, 21]. This outcome suggests a similar maintenance of corneal biomechanical strength, following PRK/LASIK and SMILE in comparable degree of myopia correction.

THE IMPACT OF CAP THICKNESS ON CORNEAL BIOMECHANICS

Many clinical reports revealed that the increased cap thickness induces less corneal biomechanics, weakening the creation of the thinner cap [22]. The comparison of 140 μm and 110 μm cap in the study of Wu et al. or 160 μm and 100 μm cap in the study of El-Massry et al., showed higher postoperative corneal biomechanical strength in favor of thicker cups [23, 24]. The results are consistent with the experimental study by Randleman, which proved the higher tensile strength in the anterior stroma than in the posterior stroma of the cadaver eyes [25]. The above outcomes suggest the main role of the anterior stroma in the overall corneal biomechanical strength [25]. On the other hand, in patients treated for high myopia, increased cap thickness may result in the excessive reduction of posterior residual stromal thickness (RST) leading to unintended weakening of the cornea [26]. Thus, in higher degree of myopic refractive error, especially in myopic astigmatism, the cap thickness should be planned carefully. To confirm the role of cap thickness in the biomechanical strength of the cornea, further clinical studies should be performed, with unification of study groups and treatment parameters [26].

THE IMPACT OF FLAP THICKNESS ON CORNEAL BIOMECHANICS

In the experimental study on human cadaver eyes, Knox Cartwright et al. investigated the influence of vertical side cuts, horizontal delamination incision and complete FS-LASIK flap creation on corneal biomechanical strength [4]. Each type of the corneal incision was performed in two variants of FS-LASIK flap thickness – 90 μm and 160 μm [4]. Authors reported that the corneal strength was significantly lower in eyes with 160 μm flap thickness in comparison with 90 μm flaps [4]. In addition, the study revealed that vertical side cuts cause more decrease in corneal strength than horizontal incisions [4]. Similar results were also obtained by other authors in the numerous clinical in vivo studies, confirming that corneal biomechanical parameters such as CH and CRF decrease significantly with the increase of LASIK-flap thickness [13, 21, 27–29].

CORNEAL BIOMECHANICS AFTER HYPEROPIC LASER VISION CORRECTION

The influence of hyperopic laser vision correction (LVC) on corneal biomechanics has been recently reported in a few studies. De Medeiros et al. assessed the CH and CRF values at 1-week post-FS-LASIK in myopic and hyperopic eyes. The study groups were similar in terms of preoperative corneal biomechanical parameters, flap thickness, magnitude of refractive error, volume of tissue removal, preoperative CH and CRF, and simulated keratometry values [30]. The study reported the greater decrease in CH and CRF in myopic rather than hyperopic ablation profiles [30]. The authors concluded that the spatial profile and volume of corneal ablation together with preoperative corneal biomechanical stiffness are important factors that influence corneal biomechanics after FS-LASIK [30]. Moreover, the paracentral hyperopic ablation profile in anatomically thicker peripheral cornea can explain statistically less common corneal ectasia following hyperopic FS-LASIK [30]. In the recent experimental ex vivo study on human fellow eye corneas, Spiru investigated the influence of hyperopic SMILE vs. FS-LASIK on corneal biomechanics [31]. To assess elastic and viscoelastic properties of donor corneas, authors applied two-dimensional biomechanical measurements: stress strain-curve and stress relaxation-curve. The results of the study revealed no difference between hyperopic SMILE and FS-LASIK in terms of effective elastic modulus in stress-strain and stress-relaxation measurements [31]. The authors concluded that in contrast to myopia correction, SMILE and FS-LASIK in hyperopia correction have a similar effect on the corneal biomechanics in ex vivo studied fellow human corneas [31].

CONCLUSIONS

In conclusion, the PRK/LASEK and SMILE in myopia correction, compromise the corneal biomechanics less than the LASIK/FS-LASIK. The thicker caps in SMILE and thinner flaps in LASIK/FS-LASIK are beneficial in maintaining the corneal biomechanical integrity. The hyperopic laser vision correction seems to have less effect on corneal biomechanics weakening than myopic correction. The future research over corneal biomechanics after laser vision correction should standardize the study groups in terms of refractive error degree and type, ablation profile, optical zone, preoperative corneal thickness, percentage of tissue removed, lenticule thickness, residual stromal bed left and patients' age.

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Authors' contributions:
Zofia Pniakowska: literature review and selection, writing of the manuscript, editorial corrections; Joanna Wierzbowska: concept of the manuscript, content supervision; Piotr Jurowski: content supervision.

Conflict of interest:
None.

Financial support:
None.

Ethics:
The content presented in the article complies with the principles of the Helsinki Declaration, EU directives and harmonized requirements for biomedical journals.