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ORIGINAL ARTICLE

Percent tissue altered index calculator for screening candidates for laser-assisted *in situ* keratomileusis

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Abstract

Purpose: The purpose of the study was to provide a percent tissue altered (PTA) calculator to screen candidates for laser-assisted *in situ* keratomileusis (LASIK) and to conduct a calculation-based study to predict under which conditions patients otherwise qualifying for LASIK would have a PTA value above 40%.

Methods: Excel software was used to create a PTA calculator based on pre-operative values of pachymetry, manifest refraction spherical equivalent (MRSE), treatment zone, and flap thickness. The calculator was tested in 240 theoretical scenarios of eyes with MRSE -1D to -14D and pachymetry of 450–600 μm. We filtered the dataset according to our institution's safety criteria [MRSE <7, pachymetry 500 μm, residual stromal thickness (RST) >300 μm] and a combination of more permissive criteria described in the previous literature (MRSE <8D, pachymetry 480 μm, RST 280 μm).

Results: The calculator allowed prediction of PTA and RST. With a flap thickness of 120 μm and treatment zone of 6.7 mm, both sets of criteria resulted in scenarios of PTA above 40%, all in eyes with MRSE >6D. Maximal PTA was 42.4% using our institution's criteria and 46.1% using the more permissive criteria. When flap thickness was lowered to 110 μm and the treatment zone to 6.5 mm, only two scenarios remained, in which PTA was slightly higher than 40% (MRSE 7D; pachymetry 510 μm, 520 μm; PTA 40.9%, 40.1%, respectively).

Conclusion: Commonly used safety limits for LASIK surgery do not completely exclude patients at with PTA above 40%. The described calculator can assist surgeons in identifying these scenarios using their own safety criteria and treatment parameters.

Introduction

The pre-operative evaluation of patients scheduled for refractive surgery is intended, in part, to identify those at risk of development of post-operative corneal ectasia. This dreaded complication has been associated mainly with laser-assisted *in situ* keratomileusis (LASIK), but it can also occur after photoreactive keratectomy and small excision lenticule extraction.[1,2] The estimated incidence of progressive corneal ectasia after LASIK is 0.2%.[3] Risk factors include intrinsic biomechanical properties such as abnormal corneal topography as well as iatrogenic changes in corneal biomechanics such as the amount of tissue altered, low residual stromal thickness (RST), and amount of remaining load-bearing tissue.[4,5] Other clinical factors may also play a role, including thin corneas, high myopia, and young age.[4]

Several grading systems have been developed for the detection of patients at risk of post-LASIK corneal ectasia.[6-10] The main parameters included are corneal keratometry, oblique cylinder, pachymetry, posterior surface elevation, difference between the inferior and superior corneal diopteric power, and posterior-over-anterior best sphere fit.[6] The ectasia risk score system incorporates RST together with corneal topography, refractive correction, and patient age.[7,8]

The percent tissue altered (PTA) index was introduced in 2014 by Santhiago *et al.*[11] to reflect the proportion of corneal tissue that would be biomechanically modified by refractive

surgery. It is calculated by the formula: PTA = (FT + AD)/CCT, where FT = Flap thickness, AD = Ablation depth, and CCT = Pre-operative central corneal thickness.[12] In their preliminary study, Santhiago *et al.*[11] found that a PTA value of more than 40% could predict post-LASIK ectasia in patients with normal pre-operative corneal topography with a sensitivity of 97% and specificity of 89%. Support for these findings was provided by a case-controlled study showing an increased risk of corneal ectasia in patients with PTA more than 40%.[13] However, a retrospective analysis of 126 normal eyes that underwent LASIK with PTA more than 40% did not document a single case of iatrogenic post-operative ectasia.[14] Moreover, in 19 eyes, PTA was more than 47%, the value at which Santhiago *et al.*[12] reported 100% specificity. Similar results were reported by Djodeyre *et al.*[15]

The aim of this study was to increase our understanding of the added value of the PTA index in a real-world setting. Using an Excel-based calculator, we sought to predict conditions under which patients qualifying for LASIK on the basis of commonly used dioptric and pachymetric safety limits would have a PTA index of more than 40% or more than 47% were the surgery performed.

Methods

A calculation-based study was conducted. Excel software (Microsoft Inc., Redmond, CA). was applied to determine the predicted RST and PTA in 224 theoretical scenarios of eyes with spherical equivalent refractive errors of -1D to -14D and pachymetry readings of 450–600 μm. We assumed a standard LASIK flap thickness of 120 μm and ablation depth of 15 μm for each diopter of refractive error, corresponding to a 6.7 mm treatment zone according to the Munnerlyn formula.[16] The scenarios were filtered to exclude eyes with pachymetry readings of <500 μm or manifest refractive spherical equivalent (MRSE) more than -7D, or RST <300 μm, as per the safety limits used in our institution. To demonstrate the added value of PTA with more permissive criteria, we excluded scenarios with pachymetry readings of <480 μm or MRSE more than -8D or RST <280 μm.

The calculator is available for viewing and editing [Supplementary File 1]. As surgeons use different flap thicknesses and treatment diameters to reduce the depth of ablation in borderline cases, these parameters can be altered as needed.

Results

Table 1 presents the scenarios that resulted in PTA <40% using our institution's exclusion criteria and using our more permissive criteria. The complete dataset is available in the interactive Supplementary File 1. In addition, Figure 1 depicts the MRSE, corneal pachymetry, and RST values for all eyes included in the complete dataset study, divided into two groups: PTA more than 40% (in red) and PTA <40% (in green). An animated 4D graph can be found using the link below. The code used to generate the 4D graph is also described in the link below and can be applied by readers who want to alter and use the graph [Link to the animated graph].

Table 1: Predicting PTA more than 40% by biomechanical properties in candidates for LASIK using two sets of criteria*

Corneal thickness (μm)	MRSE (D)	RST (μm)	PTA (%)
Assuta Optic Laser Center criteria – corneal thickness≥500 μm, MRSE ≤-7D, RST≥300 μm			
510	6	300	41.1
520	6	310	40.3
530	7	305	42.4
540	7	315	41.6
550	7	325	40.9
560	7	335	40.1
Permissive criteria – corneal thickness≥480 μm, MRSE ≤-8D, RST≥280 μm			
490	6	280	42.8
500	6	290	42.0
510	6	300	41.1
520	6	310	40.3
510	7	285	44.1
520	7	295	43.2
530	7	305	42.4
540	7	315	41.6
550	7	325	40.9
560	7	335	40.1
520	8	280	46.1
530	8	290	45.2
540	8	300	44.4
550	8	310	43.6
560	8	320	42.8
570	8	330	42.1
580	8	340	41.3
590	8	350	40.6

LASIK: Laser-assisted *in situ* keratomileusis, MRSE: Manifest refraction spherical equivalent, RST: Residual stromal thickness, PTA: Percent tissue altered, *Calculations were done using a flap thickness of 120 μm, and treatment zone of 6.7 mm

Briefly, in both sets of exclusion criteria, in all scenarios, in which PTA was more than 40%, MRSE was ≥6D or higher. Maximal PTA was 42.4% using our institution's criteria set and 46.1% using the more permissive criteria set. The PTA was smaller than 47% in all eyes. Lowering flap thickness to 110 μm and the treatment zone to 6.5 mm while using the criteria set of our institution left only two scenarios, in which PTA was slightly larger than 40% (MRSE 7D; pachymetry 510 μm, 520 μm; PTA 40.9%, 40.1%).

Discussion

Cut-off values for the disqualification of LASIK candidates vary among institutions and surgeons and depend not only

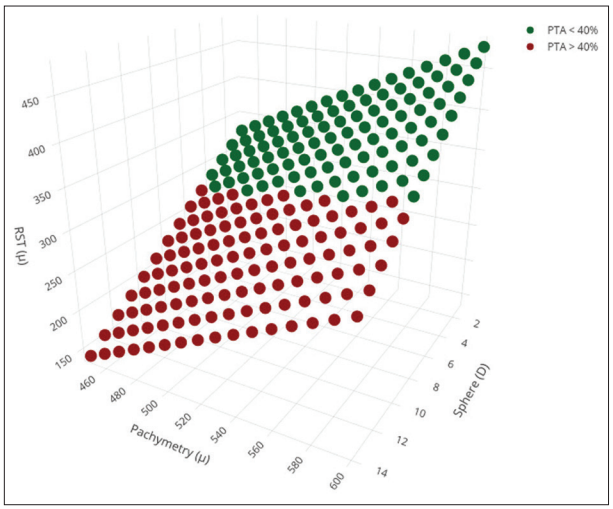

Figure 1: A four-dimensional graph showing theoretical scenarios of different values of manifest refraction spherical equivalent, corneal thickness, and residual stromal thickness. Eyes with predicted percent tissue altered (PTA) values >40% appear in red, and eyes with predicted PTA values below 40% appear in green

on pachymetry readings and MRSE values but also on corneal geometry (topography and tomography, family history of corneal ectasia, etc.). Our literature search yielded several different cut-offs for pachymetry and MRSE for LASIK candidates: In studies conducted in the United States using cut-offs approved by the Food and Drug Administration and American Academy of Ophthalmology, the lowest value of CCT for LASIK candidates was 450 µm and the highest values of MRSE and RST were -14D and >250 µm, respectively.[17,18] In studies conducted in Europe using cut-offs recommended by the European Society of Cataract and Refractive Surgeons, we found CCT values as low as 480 µm, RST values of 250–340 µm, and MRSE values of 8–10D for treatments for myopia.[19,20]

The present study showed that when we applied the cut-off values employed in our institution, there were only two scenarios, in which PTA was slightly higher than 40% (40.1%, 40.9%). Applying a combination of more permissive but still reasonable criteria resulted in several additional scenarios, in which PTA was more than 40%. All but one of these scenarios occurred when MRSE was 7D or larger. The reliability of PTA above 40% as a risk factor for post-LASIK ectasia remains unclear. Ectasia after LASIK is rare, and it can occur even many years after the surgery was performed. Thus, the failure of some studies to find cases of ectasia on *post hoc* analysis of small series of patients with PTA more than 40% or more than 47%[12,14,15,21] does not mean that performing LASIK with large PTA values is safe.

Conclusion

In the present study, we demonstrated that limiting MRSE to -7D, corneal thickness to 500 µm, and RST to 300 µm will exclude almost all patients in whom LASIK would result in a PTA value above 40%. The attached calculator makes it possible for all surgeons or institutions to evaluate their own safety limits in terms of the PTA index and identify specific scenarios in which PTA would exceed 40%, when ablation rather than LASIK might be a safer option.

Declaration of Conflicting Interests

The authors declare that there is no conflicts of interest.

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Supplementary File 1

Supplementary File 1

Title: Percent tissue altered (PTA) Index Calculator

Summary: An interactive file using different combinations of cut-off values for the calculation of different treatment areas, thicknesses, and PTA values for the reader's convenience. Treatment zone diameter, flap thickness, and cut-offs of maximal manifest refraction spherical equivalent, minimal residual stromal thickness, and minimal pachymetry can be altered and customized by users of the file.