Using artificial intelligence in the interpretation of corneal topography for laser vision correction

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ABSTRACT

PURPOSE: Development and validation of an artificial intelligence program for interpretation of corneal tomography.

SETTING: Ebsar eye center, Benha, Qalyopia, Egypt.

METHODS: In this retrospective cohort study, we analyzed the tomography of 611 eyes of 4 groups of patients using manual interpretation and Hamed's Interpreter as well.

RESULTS: There is a statistically significant difference between group 2 and group 1 regarding the inter eye differences in thinnest location (P-value 0.021) and also manifest refraction spherical equivalent (P-value 0.011). The mean of both was significantly high in group 1 (patients with postoperative ectasia) 17.0 ± 7.87 and -5.56 ± 2.16 respectively. There is a statistically significant difference between group 3 and group 1 regarding percent tissue altered (P-value <0.001) and residual stromal thickness (P-value <0.001). The mean of percent tissue altered was significantly higher among patients who had post-laser kerato-refractive surgery ectasia group (37.23 ± 5.18) while the mean of residual stromal thickness was significantly low among this group (328.25 ± 41.6). In respect to group 4, the mean of the Inter eye score was 3.38 ± 1.04, and the mean of relative thickness map was -9.2 ± 0.596. The shape of the thickness profile map curve was a quick slope in 61.5% of eyes and normal in 38.5% of eyes in group 4. Some ectasia risk factors were missed during manual interpretation of topography that led to post LVC ectasia.

CONCLUSIONS: Developing an artificial intelligence system that can interpret corneal tomography will alleviate the human errors of manual interpretation.

INTRODUCTION:

Detection of corneas with ectasia possibility comprises a cornerstone of preoperative screening for corneal laser vision correction. There are many investigation options like abnormal anterior and posterior corneal curvature[1], localized corneal thinning[2], focally decreased corneal epithelial thickness,[3] and corneal biomechanical instability.[4,5]

However, no method gives absolute sensitivity and specificity, we still need to refine the existing diagnostic tools. Inter-eye asymmetry is a famous feature of keratoconus.[6,7] research studies have investigated the inter-eye asymmetry in keratoconus patients,[7-10] because normal corneas are almost symmetric.[11-14] The investigators demonstrate the significant overlap between healthy corneas and corneas with subclinical keratoconus,[1,15] also they demonstrate the increasing sensitivity by using artificial intelligence in interpreting and assisting in the decision making of the corneal topography and tomography data.[15]

The Pentacam HR Scheimpflug tomography system (Oculus Optikgeräte GmbH, Wetzlar, Germany) has gained wide agreement in ophthalmic practice for keratoconus screening because it provides several corneal displays that have been widely investigated.[2,15-23] It has been proven that although investigating the patients' cornea with the Pentacam can diagnose many cases with subclinical keratoconus, a considerable number of patients can still go undiagnosed.[15] Some investigators have proven the most important risk factor for post- laser in situ keratomileusis (LASIK) ectasia to be the abnormal corneal topography, followed by residual stromal bed thickness, age, and preoperative corneal thickness.[24]

Other investigators have proposed a Pentacam wide step algorithm according to the Pentacam elevation, pachymetry, sagittal, and Belin-Ambrosio enhanced ectasia maps that can assist in screening surgical refractive candidates. [25-26] Other investigators attributed the post-Lasik ectasia to the percent tissue altered (PTA) and the manifest refraction spherical equivalent (MRSE) corrected by laser refractive surgery.[27]

Lasik with corneal crosslinking with riboflavin (Xtra) is a new technique, aimed at reducing corneal ectasia after Lasik. The indication of Lasik Xtra in previous studies were: young patients (younger than 24 years of age); patients with heavy eye rubbing due to severe ocular allergies; patients with normal corneas but with a family history of keratoconus; patients with thin corneas (in which risk of ectasia has been ruled out); High myopes (over – 8.0 diopters who require deep ablations); patients who require retreatments; and patients who experienced irregular flap creation. However, surface ablation with corneal crosslinking with riboflavin (CXL) is the preferred approach when keratoconus is detected. Kanellopoulus AJ has stated that, in the peripheral ablation patterns used for hyperopic treatments, CXL locks in the new corneal shape, and, therefore, regression is delayed.[28]

The ectasia risk factors have been classified as mild, moderate, and severe. If the ectasia risk factors are mild, LASIK, FEMTOLASIK, FEMTOSMILE or photorefractive keratectomy (PRK) can be done. If the ectasia risk factors are moderate, photorefractive keratotomy (PRK) or PRK XTRA is safer. However, if the ectasia risk factors are severe, no refractive surgery should be attempted.[29] Artificial intelligence programs can assist the refractive surgeons in interpretation of corneal topography and tomography to detect the ectasia risk factors.[30]

PATIENTS AND METHODS

In this research study, professor Abdelmonem Hamed developed an artificial intelligence program called (Hamed's Laser Vision Correction (LVC) Interpreter) that can detect the ectasia risk factors and interpret the refractive, topographic, and tomographic data entered by the refractive surgeon and gives a refractive report. We retrospectively evaluated Hamed's LVC Interpreter on corneal topographic and tomographic findings and corneal asymmetry values using in healthy patients and patients with post-Lasik ectasia to determine its efficacy in detecting the ectasia risk factors.

This study was a retrospective, cohort study. The written informed consent for retrospective data analysis was obtained from refractive surgery candidates during their recruiting process. The research protocol followed the tenets of the Declaration of Helsinki and the study and consent procedure were approved by the Benha University Faculty of Medicine Research Ethical Committee (approval number Rc. 4.3.2021). The records of 611 eyes who underwent laser vision correction (LVC) surgery in Ebsar Eye Center (Benha, Egypt), between April and December 2015, and who were followed up for 5 years after surgery were reviewed, the refractive, topographic, and tomographic data were reviewed conventionally by the refractive surgeons at the time of the surgery.

Inclusion criteria for LVC were:

Female and male subjects 20 years or older with stable refraction for one year with Spherical equivalent up to −10.5 D, contact lens discontinued for 1 week and rigid gas permeable lens discontinued for 3 weeks prior to the procedure, the minimum corneal thickness of 470μm at the thinnest location, a residual stromal bed of at least 300. Only patients who have completed one year of follow-up were included in this study.

Exclusion criteria for LVC were:

Unstable refraction, active ocular disease like severe dry eyes, severe allergic eye disease, uveitis, visually significant cataract or retinal disease, family history of keratoconus, past history of systemic or autoimmune diseases, previous corneal surgery, or females who were pregnant or nursing.

All patient's records were reviewed by four trained ophthalmologists (Ibrahim Abdelkhalik Elsaadani, Abdelmonem Mahmoud Hamed, Shereef Mohammed Abdelwahab, and Maha Atayia Elfayoumi) and by the Hamed's LVC interpreter as well. Each patient was subjected to slit-lamp examination of the anterior and posterior segments of the eyes, cycloplegic and subjective manifest refraction, and Pentacam HR Scheimpflug tomography ®. Pentacam examinations with acquisitions with acceptable quality (as defined by the manufacturer) were included. The following Pentacam values were analyzed: flat anterior keratometry (Ant. K1), steep anterior keratometry (Ant. K2), and mean anterior keratometry (Ant. K-Mean), mean posterior keratometry (Post. K-Mean), central apex (CA), and thinnest corneal thickness (TL) and its X and Y coordinates, central corneal thickness (CCT), Maximum keratometry (K-Max), Inferior superior index of the anterior sagittal map (I/S), Skew of the steepest radial axis (SRAX), Aspherecity (Q) value at 6mm, an average of corneal thickness progression indices (CTPI), anterior and posterior elevation at central 5 mm zone (best fit sphere), Belin/Ambrosio display (BAD) overall deviation of normality (D), pachymetry map pattern and its inferior superior difference (DD) at 5mm, pachymetry map pattern, relative map value at TL, the shape of the curve in thickness profile map, and inter-eye interpretation score.

In this study, the ectasia risk factors were classified into 3 types (Mild, moderate, and severe risk factors) according to classifications of evidence-based previous research studies[4,24] (Table 1).

Table (1) Classification of ectasia risk factors

Type of ectasia risk factors	Parameters
Mild risk factors	**1. Difference between K-max – steep K ≥ 1.0 D** **2. Pachymetry apex - TL ≤ 10 µ**
Moderate risk factors	**1. Anterior K-mean (48-50 D)** **2. Anterior sagittal map I/S index > 1.4 D** **3. TL thickness ≥ 470 - < 500 µm** **4. Belin/Ambrosio Display D-value between (1.6 - 2.6)** **5. Thickness profile map curve shape: S-shaped after 6mm** **6. Inter-eye interpretation (Score 4)** **7. Pachymetry map pattern (Dome and droplet-shaped)** **8. Relative thickness map absolute value ≥ 8.0% (e.g. 9.4%)** **9. Average of thickness progression index ≥ 1.2**
Severe risk factors	**1. Anterior K-mean > 50 D** **2. TL thickness < 470 µm** **3. SRAX ≥22◦** **4. Anterior sagittal map pattern (Butterfly, crab claw, vertical D, and clown or smiling face)** **5. Elevation front @ TL in myopia (BFS) (Automatic, 8 mm) > 8** **6. Elevation back @ TL myopia (BFS) (Automatic, 8 mm) > 17** **7. Elevation front @ TL hyperopia (BFS), (Automatic, 8 mm) > 7** **8. Elevation back @ TL (BFS), (Automatic, 8 mm) > 28** **9. Elevation front within 5 mm zone in myopia (BFTE), Regardless of refraction > 12** **10. Elevation back within 5 mm zone in myopia (BFTE), Regardless of refraction > 15** **11. Pachymetry map pattern (Bell or Globus pattern)** **12. Thickness profile map curve shape: Quick slope, S before 6mm, or Inverted slope.** **13. Inter-eye interpretation (Score 5)** 14. **Belin/Ambrosio Display D-value > 2.6**

Patients in this retrospective cohort study were classified into four groups:

1. Group 1: Patients who had post-laser kerato-refractive surgery ectasia.
2. Group 2: Patients with normal corneal topography or with mild-risk factors (table 1) and had laser kerato-refractive surgery such as PRK, LASIK, Femto-LASIK, or Femtosmile. The corneal topography [24] was defined as normal when "regular and symmetric patterns (including round, oval, or bowtie patterns) or slightly asymmetric (steepening 0.5 D and without skewed radial axis) based on placido-disc analysis."
3. Group 3: Patients with moderate-risk factors (table 1), and had PRK XTRA at the same time of PRK surgery.
4. Group 4: Patients with severe-risk factors (table 1) who were subjected to follow up only for corneal cross-linking with riboflavin whenever possible.

All eyes in our study had a preoperative and postoperative topography with the Pentacam HR system ®, and we used the tomographic data from axial maps, pachymetry maps, elevation maps, Belin/Ambrosio display map, inter-eye asymmetry data.

In this study, we used the anterior sagittal map I/S index at 3 mm zone instead of getting the superior/inferior (I/S) difference on the steep axis of the anterior sagittal map because some cases have either oblique or against the rule astigmatism, so it is not possible to get the I/S difference on the steep axis in these cases. Furthermore, we got the highest reading of the elevation back and front from the central 5 mm zone.

Statistical Analysis

Data analysis was performed using the software SPSS (Statistical Package for the Social Sciences) version 20. Quantitative parametric variables were described using their means and standard deviations or median (range) for non-parametric data. Categorical variables were described using their absolute frequencies. Kolmogorov-Smirnov (distribution-type) and Levene (homogeneity of variances) tests were used to verify assumptions for use in parametric tests. To compare quantitative data between two groups, an independent sample t-test was used to compare means when data were normally distributed and the Mann Whitney test was used when data is not normally distributed. ROC curve was used to determine the cutoff of certain continuous variables for the prediction of a health problem. The level of statistical significance was set at $P<0.05$. $p\leq0.001$ was considered as statistically highly significant

RESULTS

Group 1 (Post-Lasik ectasia group) (Number = 5 eyes)

Baseline data from group 1 were summarized in table 2 (5 eyes of 4 patients who had post-laser kerato-refractive ectasia). The age of patients ranged from 26 to 30 years with a mean of 28.75 years. All four patients had postoperative ectasia, two of them (3 eyes, 60%) had-right sided ectasia, and two of them (2 eyes, 40%) had left side ectasia. Regarding duration, till ectasia develops, it ranged from 3 to 60 months with a median of one year. One patient who underwent the Femto-smile technique had bilateral ectasia. Regarding the corneal thickness map, 62.5% of the studied eyes had concentric shapes (Table 2).

Table (2) Baseline data of the group of patients with postoperative ectasia:

Age (year)	28.75 ± 1.89	26 – 30
Elevation back	15.875 ± 5.41	7 – 23
K max - Steep K	0.917 ± 0.496	0.3 – 1.7
TL	514.75 ± 19.256	478 – 536
TL x-cordinate	0.544 ± 0.26	0.14 – 0.85
TL y-cordinate	0.738 ± 0.582	0.21 – 1.76
Flap thickness	105.0 ± 9.258	100 – 120
Time for ectasia	12[¥]	3 – 60
Manifest cylinder	-1.125 ± 0.744	-2 – 0
Topography cylinder	1.425 ± 0.694	0.4 – 2.3
Side of ectasia:		
Right	3	60%
Left	2	40%
Technique:		
Femto-smile	2	40%
LASIK	3	60%

¥ Median

Group 2 (Mild-risk group) (Number = 300 eyes)

Table 3 shows a comparison between group 1 (postoperative ectasia) and group 2 (mild risk factors), regarding preoperative baseline data. There is a non-significant difference between the studied groups regarding age, the difference of anterior K or posterior K. There is a statistically significant difference between the studied groups regarding the inter eye differences in TL (P-value 0.021) and also manifest refractive spherical equivalent (MRSE) (P-value 0.011). The mean of both values of the inter eye differences in TL and MRSE was significantly high in group 1 (17.0 ± 7.87 and -5.56 ± 2.16 respectively), however, the mean of both values was significantly low in group 2 (7.85 ± 6.4 and -2.12 ± 2.68 respectively).

Table (3) Comparison between the studied groups (groups with postop ectasia and those with minimal risk factors) regarding preoperative baseline data:

Parameters	Groups		Test	
	Patients who had post-laser kerato-refractive surgery ectasia group (Group 1)	**Patients with minimal risk group (Group 2)**	t/Z	p
Age:				
Mean ± SD	28.75 ± 1.89	30.71 ± 9.63	-0.404	0.688
Range	26 – 30	18 – 60		
Difference in ant K:				
Mean ± SD	0.33 ± 0.21	0.21 ± 0.15	-1.253	0.21
Median (Range)	0.35 (0.1 – 0.5)	0.18 (0.05 – 0.75)		
Difference in post K:				
Mean ± SD	0.13 ± 0.15	0.06 ± 0.07	-0.386	0.699
Median (Range)	0.1 (0 – 0.3)	0.05 (0 – 0.4)		
Difference in TL:				
Mean ± SD	17.0 ± 7.87	7.85 ± 6.4	-2.314	0.021*
Median (Range)	17.5 (8 – 25)	5 (0 – 24)		
MRSE:				
Mean ± SD	-5.56 ± 2.16	-2.12 ± 2.68	-2.531	0.011*
Median (Range)	-6 (-7.5, -2.75)	-2.19 (-10.5 – 7.13)		

Z Mann Whitney test *p<0.05 is statistically significant

The best cutoff of the inter eye differences in TL in the prediction of preoperative ectasia was ≥7.5 with the area under curve equal 0.849, sensitivity was 100%, specificity was 61.5%, positive predictive value (PPV) was16.7%, negative predictive value (NPV) was 100%, and accuracy was 64.3% (P<0.021). (Figure 1).

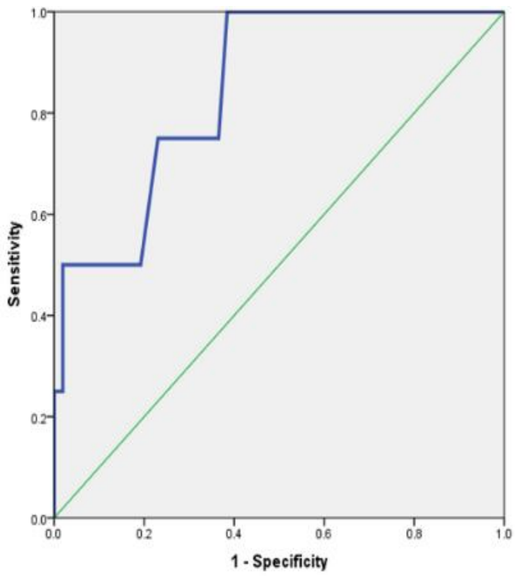

Figure 1: Receiver operating characteristic (ROC) curve showing performance of difference in TL in the prediction of post-operative ectasia among the studied patients.

The best cutoff of preoperative MRSE in the prediction of preoperative ectasia was ≤-2.69 diopters with the area under curve equal 0.074, sensitivity was 100%, specificity was 55.4%, positive predictive value (PPV) was 8.9%, negative predictive value (NPV) was 100%, and accuracy was 57.3% (P<0.011). (Figure 2).

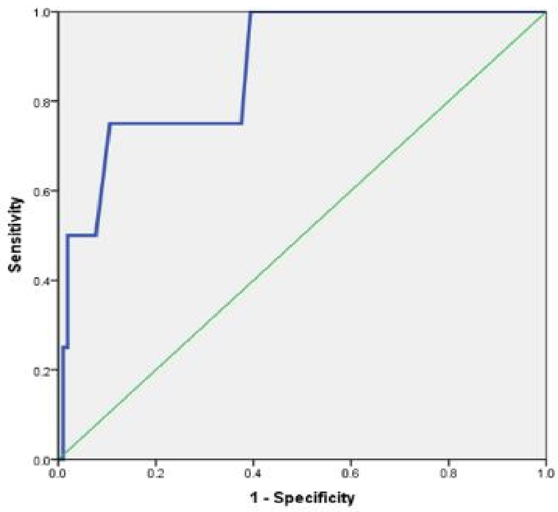

Figure 2: ROC curve showing performance of SE in prediction of post-operative ectasia among the studied patients.

Group 3 (Moderate-risk group) (Number = 228 eyes)

Table 4 shows the comparison between group 1 (postoperative ectasia) and group 3 with moderate-risk factors regarding baseline data.

There is a statistically significant difference between group 3 and group 1 regarding PTA (P-value <0.001) and residual stromal thickness (P-value <0.001). The mean of PTA was significantly high among patients who had post-laser kerato-refractive surgery ectasia group 1 (37.23 ± 5.18) while the mean of residual stromal thickness was significantly low among this group (328.25 ± 41.6), while in group 3 Mean of PTA was significantly lower (25.4 ± 3.65) while mean of residual stromal thickness was significantly high (410.07 ± 27.63). The best cutoff of PTA in the prediction of preoperative ectasia was ≥29.795 with the area under curve equal 0.98, sensitivity was 100%, specificity was 92.1%, positive predictive value (PPV) was 72.7%, negative predictive value (NPV) was 100%, and accuracy was 93.5% (p<0.001). (Figure 3) The best cutoff of residual stromal thickness in the prediction of preoperative ectasia was ≤390.5 µ with the area under curve 0.98, sensitivity 100%, specificity 92.1%, positive predictive value (PPV) 72.7%, negative predictive value (NPV) 100%, accuracy 93.5% (P<0.001). (Figure 4).

Table (4) Comparison between the studied groups (groups with postop ectasia and those with two minimal or moderate risk factors) regarding baseline data:

Parameters	Groups: Patients who had post-laser kerato-refractive surgery ectasia group (Group 1)	Groups: Patients with two minimal or moderate risk group (Group 3)	Test: t	Test: p
Age:				
Mean ± SD	28.75 ± 1.89	30.89 ± 9.99	-0.42	0.679
Range	26 – 30	20 – 60		
PTA:				
Mean ± SD	37.23 ± 5.18	25.4 ± 3.65	7.73	<0.001**
Range	31.7 – 44.7	18.59 – 38.5		
Residual stroma thickness:				
Mean ± SD				
Range	328.25 ± 41.68	410.07 ± 27.63	-6.941	<0.001**
	275 – 391	361 – 470		

**p≤0.001 is statistically highly significant   t independent sample t test

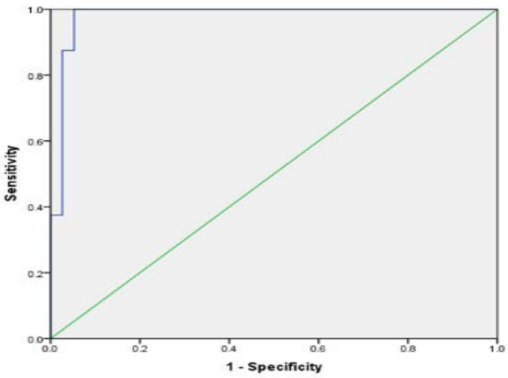

Figure 3: ROC curve showing performance of PTA in prediction of post-operative ectasia among the studied patients.

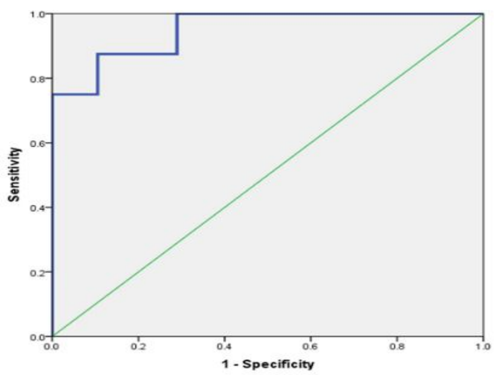

Figure 4: ROC curve showing performance of residual stroma thickness in prediction of post-operative ectasia among the studied patients.

Group 4 (severe-risk group) (Number = 78 eyes)

The preoperative relative thickness map average ranged from -9.9 % to -8.1 % with a mean of -9.2±0.6 %. The inter-eye score ranged from 1 to 4 with a mean of 3.38±1.04. Regarding thickness profile map curve shape, 48 eyes (61.5%) of patients had a quick slope and 30 eyes (38.5%) had a gradual sloop curve (Fig. 5).

Risk factor / Type of surgery	Normal tomography or tomography with mild risk factors	Tomography with moderate risk factors	Tomography with sever risk factors
PRK/SMILE/ LASIK/Femto lasik	✓	X	X
PRK or PRK (XTRA)	NA	✓	X
FU for CXL or CXL	NA	NA	✓

Figure 5: Laser Vision Correction Decision Making Nomogram.

DISCUSSION

The incidence of ectasia post-LVC was found to be 0.03-0.66% in various studies, the ectasia has been postulated to occur due to changes in the strength of the cornea due to tissue removal, corneal collagen cross-linking with riboflavin, is a proven procedure to improve the strength of corneas in patients with keratoconus, The selection of the refractive procedure (PRK/LASIK/SMILE) to be combined with simultaneous corneal collagen cross-linking, may decrease the incidence of post-LVC ectasia occurrence. Hence, the biomechanical stability of LASIK Xtra may be questionable, where in addition to tissue removal and the decrease in corneal thickness, a LASIK flap is also created which adds to the corneal weakening. This may lead to an increase of biomechanical instability and the simultaneous corneal collagen cross-linking done with the purpose of future prophylaxis from ectasia, may not be effective enough in that purpose, the use of simultaneous corneal collagen cross-linking with LVC at present is recommended in borderline corneas which may develop post-LVC ectasia. [31]

Risk factors for post-laser keratorefractive ectasia have been extensively studied. In previous research studies, the cutoff values, such as a preoperative corneal TL of 500 µm, a residual stromal bed of 250 µm, the myopia of more than -8.0 D, and patients aged younger than 25 years, were all considered potential risk factors for ectasia.[3,12–14] However, it was subsequently found that when these individual factors were considered in isolation to define the risk for ectasia development, false positives were generated.[15] In our study, the group one (eyes with postoperative ectasia); the mean of residual stromal bed (328.25 ± 41.68µm, (range 275 – 391)), MRSE (-5.56± 2.16 D, (range -7.5, -2.75)), minimum corneal thickness (514.75 ± 19.256 µm, (range 478 – 536), and patient age (28.75± 1.89 years, (range 26 – 30)).

The Ectasia Risk Score System (ERSS) was invented to specify a risk weight to preoperative and operative parameters and merged the specified risk factors as a point method to estimate the risk for developing ectasia after laser kerato-refractive surgery for every patient. Abnormal preoperative corneal topography recognized by Placido index, young patient age, thin corneal thickness, and the higher attempted refractive correction were the designated risk factors. Ectasia Risk Score System (ERSS) has been evaluated retrospectively in several research studies, it achieved 92% sensitivity and 94% specificity, depending on an ERSS score of higher than or equal to four (high risk for ectasia).[32] In this series, 46% of eyes had abnormal preoperative corneal topography.

A previous study by Binder and Trattler [33], found that eyes with normal preoperative corneal topography, the ERSS may not precisely prophesy and some patients remain at risk of getting post-laser keratorefractive ectasia. They also found that the ERSS overrated the ectasia possibility in eyes with normal preoperative corneal topography when they followed up the patients for one year after surgery. Some healthy corneas with normal topography preoperatively have been reported to evolve ectasia after laser vision refractive surgery.[18]

When the ERSS was designed, topography was scored based on topography index and patterns only. In spite, the topography is a sensitive method of diagnosing keratoconus,[19,20] interpretation of corneal topography relies on the subjective interpretation of the ophthalmologist and can be changeful.[21] Artificial intelligence systems compiled corneal topography imaging with other information to detect forme fruste keratoconus have been designed. They have been improved by tomography or pachymetry mapping to determine anterior and posterior cornea elevation with pachymetric differences across the cornea to distinguish between eyes with forme fruste keratoconus and healthy ones.[5,22–24]

Pentacam HR® uses slit-scanning technology for corneal topography analysis. On its own, it does not give an objective assessment of ectasia risk but instead relies on the subjective interpretation of the color maps and indices by the ophthalmologist.

In our study, we discovered that some ectasia risk factors were missed during manual interpretation of topography that led to post LVC ectasia (group 1). Hamed's LVC Interpreter has internal algorithms that interpret the entered topography and tomography data, detect the risk factors and gives the ophthalmologists an electronic refractive report. This report shows to the surgeon the most suitable surgical procedure of choice for each individual laser vision correction case, also it can give the refractive surgeon warning messages if the cutoff values exceeded; such as if the residual stromal bed become smaller than 300 µm or if the percentage tissue altered (PTA) exceeded the cutoff value of 40% of total corneal thickness. This Hamed's LVC Interpreter was dependent on data driven from evidence-based previous studies [2, 3-4,12-15,19, 22-34] (ectasia risk factors [24], inter-eye Asymmetry Score [4], Belin/ Ambrósio Display [25], ectasia risk score system [34] and can be downloaded to be evaluated by refractive surgeons (Supplement 1), An illustrating movie (Supplementary Video 1) for Hamed's LVC Interpreter is going to be attached as well.

At the end of this study, we encourage refractive surgeons to use Hamed's LVC Interpreter which is a result of discriminant function analysis of [12, 23-34] indices, which aims to objectively indicate the topographic risk factors for ectasia and gives decision about the type of laser vision correction surgery with the safest outcome. The decision making nomogram (figure 5) means; (1) if the corneal topography and tomography is normal of if it has a mild risk factors (table1) so, PRK, LASIK, Femto-SMILE, or Femto-LASIK can be done, (2) if it has moderate risk factors (table 1) so, PRK XTRA can be done, (3) if it has severe risk factors (table 1) so, either the eye can be followed up (FU) or crosslinking with riboflavin can be done according to the severity of the risk factors in each particular case.

This Hamed's LVC Interpreter contain help buttons that illustrate to the refractive surgeons the meaning of particular data entry into its interface. Concerning topography machines, we are looking for the day when we can export the pattern and the numerical values of the corneal topography and tomography to an artificial intelligence software [35] such as Hamed's LVC Interpreter, so we can get benefit from the automated analysis of the ectasia risk factors, without the need for the manual interpretation that will be different from one surgeon to another. However, the limitation of this study was the small number of patients (5 eyes) in group 1, so a detailed study with a bigger number of eyes is recommended.

Conclusion

Subjective interpretation of the corneal topography by ophthalmologists can be changeful, so developing an artificial intelligence system to automatically interpret the corneal topography and tomography will alleviate the human errors of manual interpretation.

Conflict of Interest

Authors declare no conflicts of interest.

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Ethics declarations

Conflict of interest

Ibrahim Abdelkhalik Ibrahim, Abdelmonem Mahmoud Hamed, Shereef Mohammed Abdelwahab, Maha Attaia Elfayoumi, all authors have no conflicts of interest that are directly relevant to the content of this review.

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REFERENCES:

1. Arbelaez MC, Versaci F, Vestri G, Barboni P, Savini G. Use of a support vector machine for keratoconus and subclinical keratoconus detection by topographic and tomographic data. Ophthalmology. 2012;119:2231-2238.
2. Ambrósio R, Caiado ALC, Guerra FP, et al. Novel pachymetric parameters based on corneal tomography for diagnosing keratoconus. J Refract Surg. 2011;27:753-758.

3. Rocha KM, Perez-Straziota CE, Perez-Straziota E, Stulting RD, Randleman JB. SD-OCT analysis of regional epithelial thickness profiles in keratoconus, postoperative corneal ectasia, and normal eyes. J Refract Surg. 2013;29:173-179.
4. Galletti JG, Pförtner T, Fuentes Bonthoux F. Improved keratoconus detection by ocular response analyzer testing after consideration of corneal thickness as a confounding factor. J Refract Surg. 2012;28:202-208.
5. Ruiseñor Vázquez PR, Delrivo M, Bonthoux FF, Pförtner T, Galletti JG. Combining ocular response analyzer metrics for corneal biomechanical diagnosis. J Refract Surg. 2013;29:596-602.
6. Li X, Rabinowitz YS, Rasheed K, Yang H. Longitudinal study of the normal eyes in unilateral keratoconus patients. Ophthalmology. 2004;111:440-446.
7. Saad A, Guilbert E, Gatinel D. Corneal enantiomorphism in normal and keratoconic eyes. J Refract Surg. 2014;30:542-547.
8. Burns DM, Johnston FM, Frazer DG, Patterson C, Jackson AJ. Keratoconus: an analysis of corneal asymmetry. Br J Ophthalmol. 2004;88:1252-1255.
9. Zadnik K, Steger-May K, Fink BA, et al. Between-eye asymmetry in keratoconus. Cornea. 2002;21:671-679.
10. Henriquez MA, Izquierdo L, Mannis MJ. Inter-eye asymmetry detected by Scheimpflug imaging in subjects with normal corneas and keratoconus. Cornea. 2013;32:779-782.
11. Leung T-W, Lam AK-C, Kee C-S. Corneal shapes of Chinese emmetropes and myopic astigmats aged 10 to 45 years. Optom Vis Sci. 2013;90(11):1259-66..
12. Dingeldein SA, Klyce SD. The topography of normal corneas. Arch Ophthalmol. 1989;107:512-518.
13. Falavarjani KG, Modarres M, Joshaghani M, Azadi P, Afshar AE, Hodjat P. Interocular differences of the Pentacam measurements in normal subjects. Clin Exp Optom. 2010;93:26-30.
14. Khachikian SS, Belin MW, Ciolino JB. Intrasubject corneal thickness asymmetry. J Refract Surg. 2008;24:606-609.
15. Ruiseñor Vázquez PR, Galletti JD, Mínguez N, et al. Pentacam Scheimpflug tomography findings in topographically-normal patients and subclinical keratoconus cases. Am J Ophthalmol. 2014;158:32-40.
16. Miranda MA, Radhakrishnan H, O'Donnell C. Repeatability of oculus Pentacam metrics derived from corneal topography. Cornea. 2009;28:657-666.
17. Miranda MA, Radhakrishnan H, O'Donnell C. Repeatability of corneal thickness measured using an Oculus Pentacam. Optom Vis Sci. 2009;86:266-272.
18. Savini G, Barboni P, Carbonelli M, Hoffer KJ. Agreement between Pentacam and videokeratography in corneal power assessment. J Refract Surg. 2009;25:534-538.
19. Ambrósio R, Alonso RS, Luz A, Coca Velarde LG. Corneal thickness spatial profile and corneal-volume distribution: tomographic indices to detect keratoconus. J Cataract Refract Surg. 2006;32:1851-1859.
20. Delrivo M, Ruiseñor Vázquez PR, Galletti JD, et al. Agreement between Placido topography and Scheimpflug tomography for corneal astigmatism assessment. J Refract Surg. 2014;30:49-53.
21. Bae GH, Kim JR, Kim CH, Lim DH, Chung ES, Chung T-Y. Corneal topographic and tomographic analysis of fellow eyes in unilateral keratoconus patients using Pentacam. Am J Ophthalmol. 2014;157:103-109.
22. Belin MW, Ambrósio R. Scheimpflug imaging for keratoconus and ectatic disease. Indian J Ophthalmol. 2013;61:401-406.
23. Ambrósio R, Nogueira LP, Caldas DL, et al. Evaluation of corneal shape and biomechanics before LASIK. Int Ophthalmol Clin. 2011;51:11-38.
24. Randleman JB, Woodward M, Lynn MJ, et al. Risk assessment for ectasia after corneal refractive surgery. Ophthalmology. 2008;115:37-50.
25. Belin MW, Ambrosio R Jr. Corneal ectasia risk score: statistical validity and clinical relevance. J Refract Surg. 2010;26:238–40.
26. Motlagh MN, Moshirfar M, Murri MS, et al. Pentacam Corneal Tomography for Screening of Refractive Surgery Candidates: A Review of the Literature, Part I. Med

Hypothesis Discov Innov Ophthalmol. 2019;8(3):177–203.

27. Chan C, Saad A, Randleman JB, et al. Analysis of cases and accuracy of 3 risk scoring systems in predicting ectasia after laser in situ keratomileusis. J Cataract Refract Surg 2018; 44:979–992.
28. Kanellopoulos AJ. Long-term safety and efficacy follow-up of prophylactic higher fluence collagen cross-linking in high myopic laser-assisted in situ keratomileusis. Clin Ophthalmol. 2012;6:1125-1130.
29. McMahon TT, Szczotka-Flynn L, Barr JT, et al. A new method for grading the severity of keratoconus: the Keratoconus Severity Score (KSS). Cornea. 2006;25:794-800.
30. Lopes BT, Ramos IC, Salomão MQ, et al. Enhanced Tomographic Assessment to Detect Corneal Ectasia Based on Artificial Intelligence. American Journal of Ophthalmology 2018; 195: 223-232.
31. Brar S, Gautam M, Sute SS, Ganesh S. Refractive surgery with simultaneous collagen cross-linking for borderline corneas - A review of different techniques, their protocols and clinical outcomes. Indian J Ophthalmol. 2020;68(12):2744-2756
32. Randleman JB, Trattler WB, Stulting RD. Validation of the Ectasia Risk Score System for preoperative laser in situ keratomileusis screening. Am J Ophthalmol 2008;145:813–818.
33. Binder PS, Trattler WB. Evaluation of a risk factor scoring system for corneal ectasia after LASIK in eyes with normal topography. J Refract Surg 2010;26:241–250.
34. Santhiago M, Giacomin N, Smadja D, et al. Ectasia risk factors in refractive surgery. Clin Ophthalmol. 2016;10:713-720.
35. Abdelwahab SM, Hamed's AM, Bayoumy ASM, Elfayoumi MA. Topography-Guided Femto-LASIK in Virgin Eyes: Treating Manifest versus Measured Astigmatism. Clin Ophthalmol. 2020;14:4423-4430.