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The ABCD grading system in assessment of corneal cross-linking effect in keratoconus with different cone locations

Iva Krolo[a], Aida Kasumović[a,*], Ines Matoc[a], Ivan Sabol[b], Ivana Radman[a], Mirko Ratković[c]

[a] University Department of Ophthalmology, University Hospital Center Sestre milosrdnice, Vinogradska cesta 29, 10 000 Zagreb, Croatia
[b] Division of Molecular Medicine, Rudjer Boskovic Institute, Zagreb, Croatia
[c] University Eye Hospital Svjetlost, School of Medicine University of Rijeka, Zagreb, Croatia

KEYWORDS
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Abstract
Purpose: The aim of this study was to analyse the postoperative corneal cross-linking results of corneal parameters and the ABCD grading system, depending on the cone location.
Methods: Thirty eyes of 25 patients with keratoconus (KC), who received the corneal cross-linking (CXL) treatment, were included in this study. The exclusion criteria were: patients under 18 years of age, corneal pachymetry less than 400 μm, corneal scarring, history of ocular trauma, history of ocular surgery, and corneal pathology other than KC. Patients were examined at the baseline visit, and followed-up at three, six, and twelve months after the CXL. All patients underwent visual acuity and Scheimpflug tomography at all visits. Progression parameters, keratometries, and ABCD grading were compared between the visits. Patients were classified into two groups: central and paracentral cones group (within the central 5 mm corneal zone) and peripheral cones group (outside the central 5 mm corneal zone), based on X-Y coordinates of maximal keratometry (Kmax).
Results: Parameter A remained relatively stable throughout the follow-up period in both groups. Parameter B and parameter C showed a significant increase in both groups postoperatively. Parameter D showed stability at the 6-month post-CXL visit in the peripheral KC group, while the central and paracentral KC group showed improvement at the 12-month post-CXL visit.
Conclusion: There was no significant difference in the postoperative response between different cone locations in the ABCD grading system, when classifying according to the Kmax, except an earlier recovery of the parameter D in peripherally located cones.

Introduction

Keratoconus (KC) is a common, non-inflammatory, mostly bilateral disorder of the cornea, where a portion of it

* Corresponding author.

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becomes thinner and bulges forward in a cone-shaped manner. Changes in the corneal shape may lead to an impairment in visual quality, increased sensitivity to light and glare, and image distortion.[1] Corneal tomography has enabled the detection of the corneal ectasia at an earlier stage than was previously possible, as it can detect subtle changes of the cornea that occur before the loss of corrected distance visual acuity and typical slit-lamp microscopy findings.[2]

Corneal cross-linking (CXL) with riboflavin and ultraviolet (UV) light is a minimally invasive procedure for the treatment of keratectasia via an increase of the mechanical and biomechanical stability of the stromal tissue. The aim is to halt the KC progression by creating new chemical bonds (cross-links) between collagen fibrils in the corneal stroma through localised photo polymerisation.[3,4]

Classification of KC based on cone location may reveal differences in its pathology, but more importantly, can influence visual acuity and the outcomes of the CXL procedure.[5–8] The literature refers to the cone as central, paracentral, or peripheral when the cone apex is within the central 3 mm zone, between 3 and 5 central zones, or out of the 5 mm central zone, respectively. Centrally located cones exhibit a higher rate of corneal flattening, as well as visual acuity improvement, after CXL treatment.[9] Eyes with eccentric cones have a higher rate of progression after CXL. This is explained by the fact that ultraviolet light used during CXL treatment is delivered in a flat, perpendicular emission plane.[10–12]

In addition to allowing us to accurately localise the cone apex, Scheimpflug camera-based devices also offer integrated systems for assessing the severity of the disease, taking into account a variety of corneal parameters and indices. So far, the literature has proposed several classification systems for KC, amongst which the oldest and most frequently used one is the Amsler-Krumeich (AK) classification system.[13–17] It classifies KC into four stages based on the mean corneal power, astigmatism, transparency, and corneal thickness.[17] A new classification system, called the ABCD grading system, on the contrary, does not rely solely on the anatomy, but combines it with the functional performance. Besides the tomographic parameters, it incorporates the visual acuity in final gradation, which exceeds limitations of previous systems and leads to more accurate monitoring of the disease progression.[18] The ABCD grading system has been incorporated in the OCULUS Pentacam software as part of the Topometric/Keratoconus display and Belin ABCD progression display.[19] This system consists of five stages (stages 0–4) and collects data in the 3.0-mm zone, centred on the thinnest location (TL) of the cornea, for: A - the anterior radius of curvature, B - posterior radius of curvature, C - corneal thickness, and D – best corrected distance visual acuity.[18,20]

The aim of the present study was to determine the effect of CXL on corneal parameters, and whether there is a difference in ABCD grading system in different cone locations.

Material and methods

This prospective study was conducted at a tertiary eye-care centre from 2018 to 2020. It included thirty eyes of 25 patients with keratoconus, aged from 18 to 35 years, who received a corneal CXL treatment at the same institution. After detailed information was provided, an informed consent form was signed by all subjects. The study followed the tenets of the Declaration of Helsinki and all protocols were approved by the Ethics Committee of University Hospital Centre.

The study included patients diagnosed with KC who showed signs of disease progression, as mentioned in the Global Consensus on Keratoconus and Ectatic Diseases. Ectasia progression was defined by a consistent change in at least 2 of the following parameters where the magnitude of the change is above the normal noise of the testing system: steepening of the anterior corneal surface, steepening of the posterior corneal surface, thinning and/or an increase in the rate of corneal thickness change from the periphery to the thinnest point.[21] Exclusion criteria were: patients under 18 years of age, corneal pachymetry less than 400 μm, corneal scarring, history of ocular trauma, history of ocular surgery, and corneal pathology other than KC.

Under sterile conditions, the patient's eye was anesthetised by multiple applications of topical 1% tetracaine and the pupil was constricted with 2% pilocarpine. After corneal epithelium was brushed off manually in the central 9 mm zone, a CXL procedure was performed according to conventional Dresden protocol: MedioCROSS M (0.1% Riboflavin, 1.1% HPMC) was instilled every 2 min for 30 min, after which the cornea was irradiated for 30 min by a 9-mm diameter beam of UV-A radiance of 3 mW/cm^2. After the procedure, the cornea was rinsed with a balanced salt solution and a silicone hydrogel bandage contact lens was applied. Postoperatively, topical antibiotics (ofloxacin) were administered three times daily, together with preservative-free lubricant drops, until completion of the corneal epithelialisation. Subsequently, the contact lens was removed, antibiotic therapy discontinued and a steroid (fluorometholone) regime was started - three times a day for four weeks, with a gradual taper occurring after the second week. For the 3 eyes with prolonged stromal haze, we used steroids for three to six months.

Each patient underwent one preoperative (T0) and three postoperative examinations. Postoperatively, subjects were scanned at three months (T1), six months (T2), and a year (T3) after the procedure. Each visit included a slit-lamp examination, corneal tomography (Pentacam, OCULUS, Wetzlar, Germany) and visual acuity testing (Vista Vision Far-Pola, DMD MedTech charts, Italy).

The study subjects were classified into two groups depending on the cone location, which was based on X-Y coordinates of Kmax at T0 (evaluated on the Pentacam Anterior Tangential Curvature Map). The first group (G1) included subjects with central and paracentral cone location, with Kmax being within the central 5 mm corneal zone, while the second group (G2) included peripheral cones, with the Kmax being outside the central 5 mm corneal zone.

The Pentacam Belin ABCD progression display enabled the analysis of parameters A, B, C and D, taken from a 3.0 mm optical zone centred on the thinnest point of the cornea. The best corrected visual acuity was manually added into the system for each visit. Other than that, parameters monitored on the Pentacam included: anterior radius of curvature (ARC), posterior radius of curvature (PRC), thinnest location (TL), Ambrosio relational thickness maximum

(ARTmax), maximal keratometry (Kmax), flat and steep keratometry values (K1 and K2), pachymetry at the apex (PA), topographic keratoconus classification (TKC), average pachymetric progression index (AIP), Belin/Ambrosio enhanced ectasia total deviation value (BAD D), and back and front corneal elevation. Topometric indices, including the index of surface variance (ISV), index of vertical asymmetry (IVA), index of height asymmetry (IHA), index of height decentration (IHD), keratoconus index (KI), central keratoconus index (CKI), and minimum sagittal curvature (Rmin) were also analysed.

All the data were recorded in MS Office Excel tables and analysed with Medcalc (v11.4.2 Medcalc Software, Ostend, Belgium). Normality of data samples was assessed by the Kolmogorov-Smirnov test. Repeated measures ANOVA or the Friedman test (non-parametric repeated measures ANOVA) were used as appropriate to compare different timepoints (T0, T1, T2, T3). A p-value of < 0.05 was considered to be statistically significant.

Results

Thirty eyes of 25 patients were recruited in this study, seven of which were female. Their mean age was 26.3 ± 5.9 years. Based on the location of the Kmax on the Anterior Tangential Curvature Map, 17 eyes (56.66%) had central and paracentral keratoconus (G1) and 13 eyes (43.33%) had peripheral keratoconus (G2).

Parameter A remained relatively stable throughout the follow-up period in both groups. There was no significant difference between G1 and G2. Parameter B showed significant increase throughout the visits in both groups ($p = 0.01$ for both), but the trend of that increase between the groups was not significantly different. Parameter C also demonstrated significant changes throughout the visits in both groups ($p < 0.001$ for both). At the first postoperative visit, a significant corneal thinning was noted, which was then followed by the corneal thickening and stabilisation of parameter C in both groups. In both G1 and G2, TL showed similar initial thinning, with recovery and stabilisation 6-months post-CXL. Parameter D and best distance visual acuity improved in G2 earlier than in the G1 group, and this difference was noted as statistically significant ($p = 0.034$). However, these parameters recovered to the baseline values a year post-CXL in both groups. Results are shown in the Table 1.

A flattening of Kmax was noticed in both groups, although it was not significant. Mean values of both flat and steep keratometries demonstrated significantly greater change over time in G1 group ($p = 0.007$ for K1; $p = 0.008$ for K2). The K1 decreased on the final visit in the G1 group, while in the G2 group it was similar to the baseline. Although showing a decrease in the G1 group over the course of one year of follow-ups, the K2 was slightly higher in comparison to the baseline on the final visit.

The trend of change in values of AIP, BAD D, ART Max, PA, ISV, IVA, KI and back elevation did not significantly differ between the two groups in the postoperative period. IHA, IHD, Rmin, and front elevation did not show a significant change over time in each group, nor between the two groups. The central keratoconus index (CKI) demonstrated a significant difference in trend throughout the follow-up period between the groups ($p = 0.001$). In G1 group, this value slightly decreased, while in G2 group it showed a slight increase. Results of the parameters mentioned above are shown in Table 2.

Discussion

While analysing patients included in the study, we found there was not a great difference in either of the corneal parameters that help determine the cone location (such as corneal thinnest location, maximal anterior, and/or posterior corneal elevation etc.), except for the Kmax. This group arrangement, however, does not imply that Kmax alone should be the parameter depicting the cone location or shape. The literature describes various cone locations, but most studies agree with it being decentred.[9,14] Bardan et al. have proposed using the Kmax rather than the thinnest location for classifying the cone location if the purpose of this classification is to monitor progression of KC.[22] The ABCD keratoconus grading system, contrary to the Kmax that has a questionable efficacy in monitoring keratoconus progression, highlights the importance of the posterior corneal surface, and each of its components (anterior and posterior cornea, its thickness, and visual acuity) help in early detection of keratoconus progression.[19]

One of many studies have suggested that the cone location can influence the KC response to CXL.[23] The Bardan et al. study found that the majority of their KC patients had thinner corneas in the central 5 mm corneal zone, but the cone location based on Kmax varied.[22] This claim was also confirmed in the present study. When analysing the location of the corneal thinnest point in our patients, all were localised in the central 5 mm corneal zone. However, analysing the location of Kmax, almost half of the eyes showed a peripheral cone location (outside the central 5 mm corneal zone). Although an axial map is often used as a guide for the cone location, the tangential map has been reported as a superior in many aspects (including detection of subclinical KC, contact lens fitting in KC, and for the implantation of intrastromal corneal ring segments), and therefore has been used in our study.[24] The sagittal or axial curvature map is a poor indicator of the location of the cone in KC and commonly exaggerates its peripheral appearance. Using the Kmax to depict the cone location is questionable, as it fails to reflect the degree of ectasia and ignores the contribution of the posterior cornea. Studies have reported the Kmax as a poor parameter for both KC progression and CXL efficacy.[25] Duncan et al. described the ABCD keratoconus grading system for monitoring KC progression, without using the Kmax.[19]

Several methods have been described to evaluate the progression of KC and to assess the efficacy of CXL. Early systems have utilised serial topographic analysis alone, whereas many newer systems have used complex keratometric indices to describe progression.[26] Kmax is the most commonly used parameter for detecting ectatic progression, and documenting the CXL efficiency. Contrary to the number of other studies where flattening of the Kmax has been documented postoperatively, the present study did not show any statistically significant change over a 12-month postoperative period in either group, however, those values showed a slight flattening in both groups on the 6-month post-CXL visit.

Considering that Kmax alone raised concerns in monitoring KC and CXL efficacy, Belin and Duncan described the ABCD grading system which incorporates both anterior and posterior corneal curvature, as well as corneal thickness and visual performance.[20] Most of the studies published so far observed changes in this system to assess KC progression or postoperative outcomes (after corneal CXL or after intracorneal ring segment implantation).[19] Only one study of Bardan et al. observed the postoperative influence of different cone location on the ABCD grading system changes. They classified their patients according to cone location into central, paracentral and peripheral cone group.[22] Due to a smaller sample size, we merged paracentral and central cones into one group. They have observed the impact of classifying KC location based on keratometry or pachymetry on progression parameters and have concluded that the majority of progression parameters were noticed earlier when the KC was classified based on Kmax.[22]

In the present study, parameter A did not show any significant differences between two groups. Parameter B, however, showed an increase throughout the visits, similarly in both groups. Those results differ from the results of Bardan et al., that showed decreased mean values of parameter A in the central KC group, and no significant change in the peripheral KC. Moreover, their study reported no significant change of parameter B in either group.[22] The study by Sağlık and Işık evaluated the ABCD grading system in patients who were divided into different subgroups, according to the steepening and flattening degrees of Kmax values 12 months after the CXL treatment. Overall, their results showed a significant regression of the parameter A, while parameter B showed no change. The endpoints were determined in the group with >2 D flattening of Kmax. These results showed that excessive anterior surface flattening provided regression at grade A.[27]

Several studies have reported a thinning of the pachymetry measurements obtained from tomography in the early period after CXL treatment, but in the late postoperative period, these values have approached the pre-treatment levels.[28] Our results support that trend. Therefore, pachymetric measurements alone may cause errors in progression analysis after CXL. Hence, for a more accurate analysis of the effect and reliability of this parameter, a longer follow-up period is needed.

Parameter D, which represents the best distance corrected visual acuity showed a faster recovery in peripherally located cones (6 months post-CXL), while in G1, the visual recovery to baseline values was achieved after 12 months. This can be explained by the fact that keratoconus compromises the central region of the cornea to a lesser extent in peripherally located cones in comparison to the centrally and paracentrally located cones. However, Bardan et al. did not show a significant difference between groups in visual recovery during the follow-up period.[22] Overall, the value of parameter D was higher in a group with cone location that was within the central 5 mm corneal zone (worse visual acuity).

Both K1 and K2 showed similar stability at the final control visit when compared to the baseline. However, a longer

Table 1 The ABCD grading system of G1 and G2 group at the preoperative visit, three, six, and twelve months after corneal cross-linking procedure.

N = 30	T0		T1		T2		T3		Repeated measures ANOVA	Between-subjects effects
	G1	G2	G1	G2	G1	G2	G1	G2		
A	2.28 ± 1.26	1.57 ± 1.61	2.28 ± 1.03	1.78 ± 2.18	2.04 ± 1.2	1.65 ± 1.83	2.23 ± 1.44	1.81 ± 1.81	0.37	0.369
B	4.10 ± 1.88	2.93 ± 2.58	4.59 ± 1.76	3.16 ± 2.44	4.30 ± 2.01	3.27 ± 2.58	4.35 ± 2.03	3.36 ± 2.79	0.01	0.168
C	1.55 ± 0.74	1.22 ± 0.80	2.21 ± 0.85	1.74 ± 0.98	1.95 ± 0.77	1.45 ± 0.96	1.89 ± 0.79	1.36 ± 0.89	<0.001	0.141
D	1.32 ± 0.33	1.11 ± 0.19	1.48 ± 0.36	1.31 ± 0.35	1.43 ± 0.35	1.20 ± 0.30	1.31 ± 0.29	1.08 ± 0.18	0.001	0.034
ARC	6.80 ± 0.51	7.07 ± 0.63	6.78 ± 0.46	7.09 ± 0.83	6.88 ± 0.51	7.07 ± 0.72	6.89 ± 0.50	7.04 ± 0.70	0.611	0.302
PRC	5.01 ± 0.47	5.41 ± 0.70	4.87 ± 0.41	5.35 ± 0.72	4.94 ± 0.47	5.31 ± 0.73	4.92 ± 0.45	5.33 ± 0.83	0.029	0.066
TL	470.65 ± 38.83	488.23 ± 41.79	437.35 ± 43.69	460.39 ± 49.12	451.12 ± 38.49	473.77 ± 46.79	454.29 ± 39.32	477.85 ± 50.23	<0.001	0.173
DCVA	0.84 ± 0.17	0.94 ± 0.10	0.75 ± 0.18	0.84 ± 0.17	0.78 ± 0.18	0.90 ± 0.15	0.84 ± 0.14	0.95 ± 0.09	0.001	0.034

T0 − preoperative examination, T1 − 3 months postoperatively, T2 - 6 months postoperatively, T3 − one year postoperatively, G1 − group 1, G2 − group 2, A − parameter A of ABCD grading, B − parameter B of ABCD grading, C − parameter C of ABCD grading, D − parameter D of ABCD grading, ARC − anterior radius curvature calculated from a 3.0 mm optical zone centred on the thinnest point of the cornea, PRC − posterior radius curvature calculated from a 3.0 mm optical zone centred on the thinnest point of the cornea, TL − thinnest location obtained from Topometric/Keratoconus Grading Display of the Pentacam, DCVA − distance corrected visual acuity.

Table 2 Corneal parameters and indices of progression of G1 and G2 group at the preoperative visit, three, six, and twelve months after corneal cross-linking procedure.

	T0		T1		T2		T3			
N = 30	G1	G2	G1	G2	G1	G2	G1	G2	Repeated measures ANOVA	Between-subjects effects
Kmax	54.29 ± 4.84	51.16 ± 6.26	54.17 ± 4.08	51.70 ± 6.35	53.64 ± 4.25	50.87 ± 5.76	53.32 ± 4.30	51.03 ± 5.70	0.149	0.161
K1	45.17 ± 2.57	42.64 ± 1.84	44.99 ± 2.45	42.26 ± 1.96	44.99 ± 2.69	42.7 ± 1.96	44.88 ± 2.63	42.59 ± 2.08	<0.001	0.007
K2	48.92 ± 3.40	45.79 ± 2.22	48.84 ± 3.30	45.82 ± 2.48	48.50 ± 3.38	45.80 ± 2.32	49.09 ± 3.97	45.55 ± 2.41	<0.001	0.008
AIP	2.06 ± 0.50	1.76 ± 0.55	2.61 ± 0.61	2.11 ± 0.74	2.37 ± 0.56	1.97 ± 0.68	2.39 ± 0.58	2.05 ± 0.92	<0.001	0.093
BAD D	7.78 ± 2.92	6.60 ± 3.88	8.78 ± 3.06	7.63 ± 4.60	8.08 ± 3.08	7.08 ± 4.46	8.50 ± 2.87	7.13 ± 4.72	0.01	0.375
ART Max	163.71 ± 42.72	205.15 ± 119.02	117.65 ± 36.12	163.69 ± 104.88	137.24 ± 34.31	168.31 ± 90	139.88 ± 35.85	163 ± 84.24	0.002	0.173
PA	484.29 ± 36.24	503.92 ± 34.21	446.77 ± 40.07	475.69 ± 43.68	463.71 ± 40.44	493.31 ± 40.06	468.82 ± 42.67	499.92 ± 36.94	<0.001	0.063
IHA	31.57 ± 20.69	25.63 ± 18.09	32.32 ± 22.41	25.89 ± 20.85	32.62 ± 18.42	26.73 ± 20.13	28.25 ± 16.99	22.43 ± 15.93	0.638	0.291
IHD	0.11 ± 0.05	0.12 ± 0.09	0.11 ± 0.04	0.13 ± 0.09	0.11 ± 0.04	0.12 ± 0.09	0.1 ± 0.04	0.12 ± 0.08	0.053	0.593
ISV	77.12 ± 27.03	82.39 ± 54.87	81.71 ± 22.52	89.08 ± 55.67	77.24 ± 23.69	80.69 ± 49.63	75.82 ± 24.74	80.39 ± 46.16	0.008	0.714
IVA	0.83 ± 0.30	1.02 ± 0.70	0.89 ± 0.25	1.13 ± 0.75	0.84 ± 0.26	0.97 ± 0.72	0.82 ± 0.29	1.01 ± 0.63	0.015	0.315
KI	1.20 ± 0.07	1.24 ± 0.18	1.22 ± 0.07	1.23 ± 0.16	1.2 ± 0.07	1.23 ± 0.17	1.2 ± 0.08	1.2 ± 0.16	0.042	0.657
CKI	1.06 ± 0.04	1.01 ± 0.02	1.07 ± 0.04	1.01 ± 0.03	1.06 ± 0.04	1.02 ± 0.03	1.05 ± 0.04	1.02 ± 0.04	0.752	0.001
Rmin	6.25 ± 0.56	6.69 ± 0.78	6.25 ± 0.47	6.62 ± 0.80	6.33 ± 0.51	6.74 ± 0.76	6.36 ± 0.54	6.68 ± 0.72	0.145	0.105
El. F	20.41 ± 8.41	20.62 ± 14.48	21.35 ± 7.46	21.31 ± 18.32	18.94 ± 8.23	21.46 ± 17.56	18.77 ± 7.81	21.39 ± 16.88	0.192	0.773
El. B	48.24 ± 18.95	45.00 ± 30.03	55.24 ± 18.34	48 ± 34.56	50.59 ± 18.91	50.23 ± 33.73	52.24 ± 19.07	51.31 ± 38.87	0.008	0.762

T0 – preoperative examination, T1 – 3 months postoperatively, T2 - 6 months postoperatively, T3 – one year postoperatively, G1 – group 1, G2 – group 2, Kmax – maximal keratometry, K1 – flat keratometry, K2 – steep keratometry, AIP – progression index average, BAD-D – Belin/Ambrosio enhanced ectasia total deviation value, ART Max – Ambrosio relational thickness maximum, PA – pachymetry apex, IHA – index of height asymmetry, IHD – index of height decentration, ISV – index of surface variance, IVA – index of vertical asymmetry, KI – keratoconus index, CKI – central keratoconus index, Rmin – minimum sagittal curvature, Elevation F – front corneal elevation, Elevation B – back corneal elevation.

follow-up period is needed to conclude if CXL aided in halting KC in both groups. Considering previous studies, cones within the central 5 mm corneal zone had more postoperative corneal flattening comparing to the peripherally located cones.[9,11] This could be explained by decreased CXL efficiency in the peripheral cones, as opposed to that in the central cones, as intended UV rays of currently available CXL devices might not be homogeneous over the whole treating zone. The UV rays may disperse towards the periphery, with a less powerful and inconsistent beam in peripherally located cones. Therefore, the eccentric cones may exhibit worse clinical results than presumed. The second fact is called "cosine effect." This mathematical rule indicated that even with homogeneous distributed light energy, there was a relatively low treatment power in the peripheral cornea. In summary, the incidence angle of a ray with the corneal surface decreases towards the periphery, owing to the curvature of the cornea, and the light beam is falling over a wide corneal zone. Accordingly, the more peripheral cones may be exposed to less cross-linking power.[10] AIP and BAD-D values demonstrated progression in the postoperative period in the present study, as well as the ISV, IVA, and KI. Those results are most likely the result of a direct change in the corneal surface due to the CXL procedure. Back elevation in both groups showed a similar increase at the control visits in both groups. There have been many reports of increased posterior elevation after CXL.[27,29] It is suggested that posterior steepening along with anterior flattening may be the cause for the stabilisation of keratometric values after CXL.[29] Other study found no significant changes in posterior elevation after CXL.[30] These differences can be explained by ongoing ectatic changes in the posterior cornea or by the insufficiency of existing devices to analyse posterior corneal elevation after CXL.

It is also very important to note that pathophysiology of corneal ectatic disorders is primarily associated to biomechanical abnormalities, with structural instability and tomographic changes being secondary events.[21] Nowadays, planning and following of CXL treatment also includes assessment of corneal biomechanical properties.[31,32] A novel review of their role in clinical evaluation of patients with ectatic corneal disorders was published by Salomão et al.[33] The relevance of corneal biomechanical properties is fundamental in the field of refractive surgery, where it is used to identify subjects who are at a higher risk of developing ectatic corneal changes after laser vision correction.[34] Koh et al. found a correlation between biomechanical indices and corneal tomographic parameters in patients with different stages of KC, using Scheimpflug-based technologies.[35] Combining biomechanical properties with keratometric indices could be useful in staging of KC and enhancing clinical outcomes, and should be further investigated.

Conclusions

This study did not show a large difference in the postoperative response between the cones of different locations, if they are classified according to the Kmax. The changes that were noted had a similar trend in both groups. It is important to emphasise that visual acuity and parameter D were significantly better in the G2 group. Parameter A, in the present study, did not show significant postoperative changes, as demonstrated in previous studies.

The ABCD grading system could be a useful tool in assessing the efficacy of corneal cross-linking, as it is more detailed and incorporates anterior and posterior curvature, thickness measurements, and visual acuity; however a longer follow-up period is needed for more accurate information about halting the KC of different cone locations. Also, one of the limiting factors of our study was a small sample size of only 30 eyes, which may contribute to different outcomes if the sample was larger.

Conflicts of interest

The authors declare that there is no conflict of interest.

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