BIOSCIENCES BIOTECHNOLOGY RESEARCH ASIA, December 2015. Vol. **12**(3), 3067-3072

Effect of Corneal Cone Location on Corneal Curvature Changes and Uncorrected Distance Visual Acuity after Corneal Collagen Cross-Linking for Progressive Keratoconus: A one-year Survey

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DOI: http://dx.doi.org/10.13005/bbra/1990

(Received: 02 October 2015; accepted: 19 November 2015)

To assess the effect of corneal cone location on"corneal curvature Changes and Uncorrected Distance Visual Acuity (UDVA) after corneal collagen cross-linking for progressive keratoconus. This was a descriptive and analytical study conducted on 38 eyes of 27 patients aged 15-25 years, who underwent corneal cross-linking (CXL) on progressive keratoconus. Based on the location of preoperative maximum keratometry (Kmax) set by pentacam device, the patients were divided into two groups: The central and paracentral cone groups with corneal cone location of d" 3 mm and > 3 mm, respectively. The levels of uncorrected distance visual acuity and front surface curvature of the cornea of the patients were determined before and one year after surgery using a sagittal pentacam map and then compared. The UDVA significantly improved in the central cone group (-0.14 ± 0.26Log MAR (P=0.009). Similarly, the mean differences of Ks, Kf, and Kmean were statistically significant in this group (0.83±1.14D, 0.82±1.15D, and 0.84± 1.07D) (P=0.001). However, the Kmax did not show a significant difference (0.30± 1.85D (P=0.382). However, none of the variables showed a significant change in the paracentral cone group. The changes of UDVA, Ks, Kf, Kmean, and Kmax were respectively 0.001 ± 0.19 LogMAR (P = 0.001), 0.50 ± 0.92D (P=0.143), 0.67 ± 1.54D (P=0.225), 0.79 ± 1.10D (P=0.167), and -0.06 ±0.67D (P=775) in the paracentral group. None of the variables showed significant difference between the two groups. After performing CXL for progressive keratoconus, more corneal curvature flattening and improvement in UDVA occurred in eyes with centrally located cones.

Key words: Cone location, Corneal Curvature, Progressive Keratoconus, Corneal Cross-linking, Uncorrected Distance Visual Acuity.

Progressive keratoconus causes myopia, irregular astigmatism, and impairment in visual function response to structural changes and corneal stromal collagen regularity[1,2]. Continuation of the progress trend can lead to a need for keratoplasty. Therefore, corneal cross-linking (CXL) is used to stop or slow down the progression of keratoconus[3].

CXL causes photopolymerization of stromal collagen fibers by photosensitizing

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substances (such as riboflavin or vitamin B2) and UVA radiation, leading to an increase in the number of intrafibrillar and interfibrillar bonds and enhancement of stromal collagen resistance to enzymatic degeneration[4, 5]. Previous studies have shown that CXL can have useful optical and visual effects[6-11], which may be efficient in improving and stopping progressive keratoconus[12], and be used as a strategy to limit decrease vision and the need for Keratoplasty[13], while no serious complications relevant to it have been reported[3, 14-17]. In this study, the patients nearly showed 1D improvement in Mean K and 1 Snellen line of VA increment, at the end of the first year. However, it appears that due to the uniformity of UV radiation and how CXL affects (e.g. through biomechanical method), paying attention to the overall corneal shape and Max K location is of particular importance in the assessment of CXL efficiency. Thus, the decision was made to examine the effect of cone location on CXL results, including corneal frontal curvature changes and uncorrected distance visual acuity after one year.

MATERIALS AND METHODS

This descriptive-analytical study was conducted on 38 eyes of 27 patients aged 15-25 years, who underwent CXL on progressive keratoconus. CXL was done based on the following procedures: 1. Prep & drape, 2. Epithelial treatment with Alcohol 20% for 20 sec, 3. Epithelium removal, 4. Riboflavin drop application 10 times in 30 min, 5. Ultraviolet exposure for 30 min + riboflavin, and 6. Use of bandage contact lens. Antibiotic and corticosteroid drops were prescribed, afterwards.

The participants underwent the predefined tests and subsequent CXL at Farabi Specialty Eye Hospital, Tehran, Iran in 1391.

Coordinating with the head of Farabi Hospital and with the help of the refractive surgery manager and personnel responsible for the archive files, records of patients who had undergone CXL with criteria in compliance with this study, were reviewed through an observational method and the patients eligible for the required examinations were appointed one year after operation. After calling back the patients, their post-surgery UDVAs were determined and corneal front surface topographies were examined using pentacam. Meanwhile, the study data were evaluated for the 38 eyes of the whole group before and after surgery and the patients were divided into the 2 groups of central (within the range of d" 3 mm; n = 29) and paracentral (> 3 mm; n = 9) corneal cone locations (Figure 2). Then, their levels of UDVA and corneal frontal curvature changes were determined.

Finally, the data were analyzed with SPSS (version 19). The data were expressed as mean ± SD. To compare the pre- and post-operative variables of Kf and Kmax as normally distributed variables and Ks, Kmean, and UDVA Log MAR variables without normal distributions, a paired t-test and Wilcoxon test were employed, respectively. Also, t-test and Mann-Whitney test were applied to the variables with and without normal distributions to compare the two groups, respectively.

RESULTS

The results were as follows

The UDVA of the central cone group represented a significant improvement (-0.14±0.26 Log MAR (P=0.009), but did not show a significant change in the paracentral group changes and comparisons of the two groups are illustrated in Figures 3 and 4. (-0.10±0.19 Log MAR (P=1). The Comparison of mean UDVA one-year changes between the two groups, was not statistically significant (P = 0.184).

Ks and Kf in the central cone group had significant changes, respectively, as follows:

0.83±1.14 D (P=0.001); 0.82±1.15D (P=0.001)

Yet, they displayed no statistically significant changes in the paracentral cone group calculated as follows:

0.50±0.95 D (P=0.143); 0.67 ± 1.54 D (P=0.225)

And, the comparisons of the one-year changes of Ks and Kf between the two groups were not statistically significant represented as the following, respectively: (P=0.566; P=0.756)

Ks and Kf changes are independently and comparatively shown in the two groups in Figure 5.

Kmean changes in the central cone (0.84±1.071 D (P=0.001) and paracentral cone (0.79±1.10 D (P=0.167) groups were and were not significant, respectively.

Table 1. Mean and SD distributions and the distributions of mean difference and standard deviation of the variables before and 1 year after surgery (within the entire group and central cone (≤ 3 mm) and paracentral (peripheral) cone (> 3 mm) groups

Variable	Cone location	Pre-op	1-year post-op	Pre- and 1-year post-op difference	
		Mean ± SD	Mean ± SD	Mean ± SD	P-value
UDVA	All (n = 38)	- 0.56 ± 0.51	- 0.45 ± 0.42	- 0.10 ± 0.26	0.012
(Log	Central (≤ 3mm (n=29))	- 0.56 ± 0.49	- 0.42 ± 0.39	- 0.14 ± 0.26	0.009
MAR)	Peripheral (> 3mm (n=9))	- 0.55 ± 0.59	- 0.55 ± 0.52	0.00 ±0.19	1
FKs	All (n = 38)	47.36 ± 3.22	46.60 ± 3.05	0.75± 1.09	< 0.005
	Central (≤ 3mm (n=29))	48.11± 3.16	47.28± 3.00	0.83 ± 1.14	0.001
	Peripheral (> 3mm (n=9))	44.11± 2.02	44.41± 2.22	0.50 ± 0.92	0.143
FKf	All (n = 38)	44.22 ± 2.70	43.42 ± 2.82	0.79 ± 1.23	< 0.005
	Central (≤ 3mm (n=29))	44.63± 2.92	43.81± 2.93	0.82 ± 1.15	0.001
	Peripheral (> 3mm (n=9))	42.87± 1.17	42.20± 2.14	0.67 ±1.54	0.225
FKmean	All (n = 38)	45.73 ± 2.85	44.94 ± 2.82	0.79 ± 1.10	< 0.005
	Central (≤ 3mm (n=29))	46.30± 2.95	45.46± 2.84	0.84 ± 1.07	0.001
	Peripheral (> 3mm (n=9))	43.88± 1.50	43.25± 2.08	0.79 ± 1.10	0.167
FKmax	All (n = 38)	50.58 ± 3.75	50.36 ± 4.29	0.21 ± 1.65	0.421
	Central (≤ 3mm (n=29))	51.17± 3.76	50.87± 4.40	0.30 ± 1.85	0.382
	Peripheral (> 3mm (n=9))	48.65±3.16	48.72± 3.65	- 0.06 ± 0.67	0.775

UDVA: Uncorrected distance visual acuity; k: keratometry; F: Front surface of cornea ; S: steep; F: flat; Max: Maximum

Kmax changes in the central cone (0.30±1.85 D (P=0.382) and paracentral cone (-0.06±0.67 D (P=0.775)) groups were not statistically significant.

Comparisons of one-year changes of Kmean (P=0.371) and Kmax (P=0.686) between the two groups were not statistically significant.

Kmean and Kmax changes in both groups are independently and comparatively shown in Figure 6.

DISCUSSION

The CXL has been suggested as an option to efficiently control progressive keratoconus and many studies have confirmed its effectiveness (8, 18-24). In the current investigation, at entire group Mean, K became approximately 1D flatter and UDVA nearly improved to 1 Snellen line, both of which confirm the previous research.

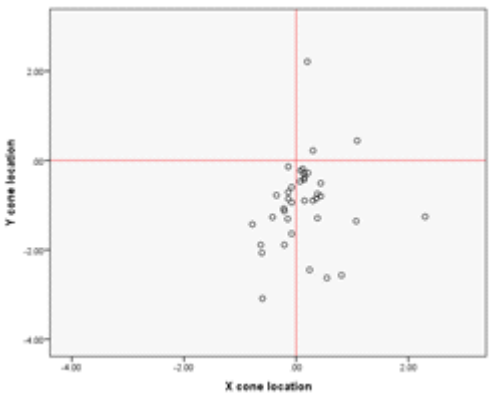

Fig. 1. Topographic cone location

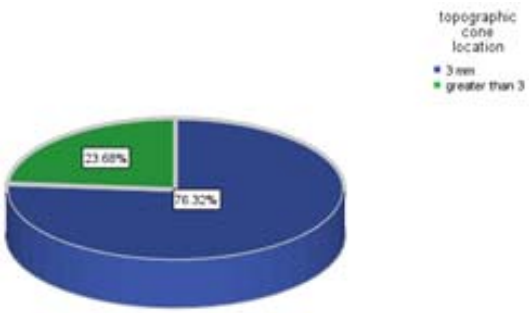

Fig. 2. Percentages of central and paracentral cone locations

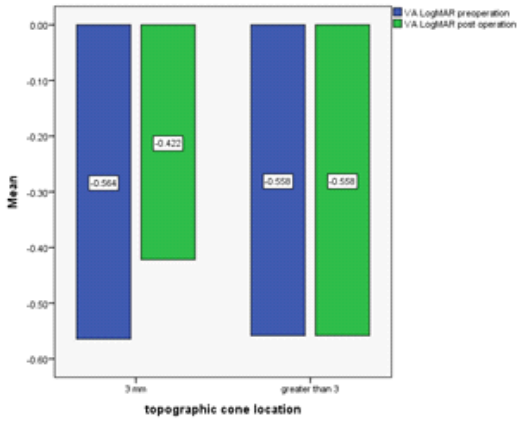

Fig. 3. The amounts and comparisons of Mean UDVA (Log MAR) in both groups before and 1 year after surgery

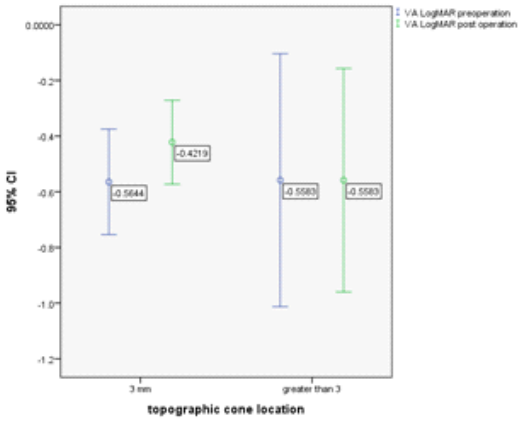

Fig. 4. One-year changes of mean UDVA Log MAR (95% CI) in the two central cone and paracentral cone groups Independently and comparatively

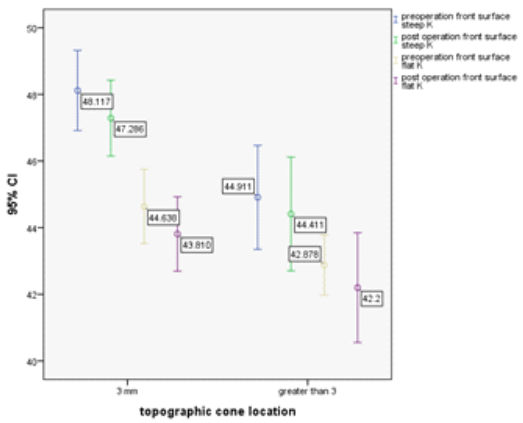

Fig. 5. Ks and Kf one-year changes in both the central cone and paracentral cone groups independently and comparatively

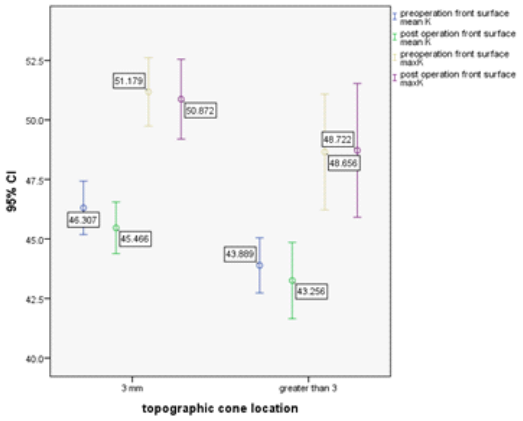

Fig. 6. One-year changes of kmean and kmax in the two central cone and paracentral cone grou and comparatively

Nevertheless, it seems necessary to have a more comprehensive view of the issues affecting CXL efficiency, including corneal overall shape, corneal hystesis, corneal resistance factor, age, gender, race, keratoconus severity, etc.

In general, the overall look suggests corneal cone location to be of particular importance with regard to corneal shape, uniform UV radiation, and the way in which the cornea is affected (e.g. via biomechanical method). Thus, the decision was made to assess the topographic cone location impact on the CXL results of this study after 1 year, incorporating corneal curvature changes and UDVA. Table 1 depicts the mean, standard deviation, mean difference and SD, and P-values of the entire group and the two central cone and paracentral groups, separately.

The results obtained are indicative of the occurrences of maximum changes towards corneal flattening and UDVA improvement, in the central cone group, previously corroborated by the study of Steven *et al*.[25]. It is known that positive changes in the center of cornea are particularly significant. Pentacam test describes the variation range of the variables. Accordingly, proving significant and positive changes in the variables (within this range) is significant, and was achieved in this research. Moreover, obtaining the above-mentioned results is not theoretically unexpected, since corneal center would be further influenced

compared to its peripheral areas, when considering corneal shape and uniformity of UV radiation. Besides, wider areas in the cornea were exposed to radiation, while less cross-linking is expected per unit area. Therefore, regarding the CXL mechanism that is deemed to be biomechanical, the overall corneal shape and corneal cone location would prove to be remarkable in the results. Nonetheless, it is recommended that multifaceted assessments including topographic cone location, be performed prior to the CXL operation, in order to predict the results. Other cases may include the Max k level before surgery, patient's age, and corneal resistance point.

Furthermore, besides suggesting further studies to be performed with larger samples, topography-guided CXL and/or changes in UV radiation level and method on the cornea with regard to corneal shape, is proposed to enhance or modify CXL effect in case of the final approval of the results of this study by the authorities. The findings of this study can be used in developing new therapeutic modalities as well as new high-tech approaches such as brain computer interface technique based on visual interface[26].

CONCLUSION

After CXL operation on progressive keratoconus, the greatest changes occurred towards corneal flattening and VA improvements in the central cone corneas. Moreover, considering the impact of corneal cone location on CXL results can be of high importance as well.

ACKNOWLEDGMENTS

The authors immensely acknowledge Dr. Mahmoud Jabbarvand Behrouz, the respected president of Farabi Specialty Eye Hospital, head nurse, optometrists, and the respectful staff of the Department of Refractive Surgery for their valuable collaboration with this study.

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