

## **AIM OF THE WORK**

The aim of work is to compare between the demarcation line depth following epithelium off and transepithelial corneal collagen cross linking in keratoconic patients using AS-OCT.

## SUBJECTS

The study was carried out on 40 eyes of 20 keratoconic patients during 2013 and 2014 at I care eye centre and Modern ophthalmic centre, Alexandria, Egypt.

### **Study design:**

A prospective, comparative study.

### **Inclusion criteria:**

- Age between 10 and 35 years.
- Keratoconus without significant corneal scarring.

### **Exclusion criteria:**

- History of ocular trauma or intraocular surgery.
- Corneal thickness less than 370 microns.
- Prior herpetic ocular infection.
- Concurrent infection.

## METHODS

All patients were appropriately informed before their participation in the study. Patients were randomly assigned to two groups, group I include 20 eyes undergone epithelium off collagen cross linking, and group II undergone transepithelial collagen cross linking. Group II subdivided into two groups with two different transepithelial techniques. Group IIA and group IIB each include 10 eyes. Pentacam was done to all patients preoperatively and they were followed up after one month by the same pentacam and AS-OCT imaging.

- **Preoperatively, all patients were subjected to:**

- 1. History taking:**

- Ophthalmologic and general history.

- 2. Examination:**

- Visual acuity testing, including best spectacle corrected visual acuity.
- Subjective refraction.
- Slit lamp examination of the cornea.

- 3. Investigations:**

Keratoconus was diagnosed using Scheimpflug topo/tomography mapping (Pentacam HR, Oculus) in respect to Amsler-Krumeich classification. In each eye, keratometric value, minimal pachymetry, and Amsler-Krumeich KC classification were evaluated.

- **Operative procedure:**

**Group I (epithelium off):**

CXL was performed under aseptic conditions.

1. Preoperative instillation of topical gatifloxacin eyedrops 3 times on the day of operation.
2. One drop of benoxinate HCL 0.4% was instilled every 5 minutes 3 times.
3. The central 7.0 to 9.0 mm of the corneal epithelium was removed by mechanical debridement using a hockey spatula (figure 19).
4. Photosensitizing solution 0.1% riboflavin in 20% dextran solution (Medio Cross D - Isotonic Standard solution with dextran (figure 20)) was then instilled every 5 minutes for 30 minutes.
5. The central cornea was exposed to an ultraviolet A source emanating from a solid-state device (CCL-HE, Peschke GmbH (figure 21)), with a working wavelength of 370 nm at surface irradiance of 3 mW/cm<sup>2</sup> for 5 minutes (surface dose 5.4 J/cm<sup>2</sup>) at a working distance of 5 cm.

6. Immediately postoperatively, a soft bandage contact lens was placed until complete re-epithelialization, intramuscular diclofenac Na 75mg ampoule (Voltaren) and dexamethasone 8mg ampoule (Epidron) were given once.
7. The patients were instructed to use
  - Topical gatifloxacin 3%(Tymer) eyedrops 4 times/day for 1 week.
  - Topical tobramycin 0.3%+dexamethasone 0.1% (optidex-T) eyedrops 4 times/day for 1week.
  - Topical artificial tears sodium hyaluronate 2% (Hyfresh) for 6 weeks.
  - Oral analgesics as required.
  - Oral vitamin C (vitacid C) effervescent.
8. Follow-up examinations were performed on day 1, 3 and 7 postoperatively. Subsequent examinations were performed at 1, 3, 6, and 12 months postoperatively and then annually.



Figure 19: Hockey knife



Figure 20: Medio Cross D – Isotonic  
Standard solution with dextran



Figure 21 :CCL-HE machine

## **Group II (transepithelial):**

The CXL procedure was carried out with the epithelium intact and was conducted under sterile operating room conditions and this group was divided into 2 groups; group IIA and IIB.

### **• Group IIA:**

1. Preoperative instillation of topical gatifloxacin eyedrops 3 times on the day of operation.
2. One drop of benoxinate HCL 0.4% was instilled every 5 minutes 3 times.
3. Photosensitizing solution (Medio Cross TE-Transepithelial solution riboflavin 0.1%, dextran T500 20%) was then instilled every 2 minutes for 30 minutes. Two eyes undergone superficial scratches prior to riboflavin instillation.
4. The central cornea was exposed to an ultraviolet A source emanating from a solid-state device (CCL-HE, Peschke GmbH), with a working wavelength of 370 nm at surface irradiance of 3 mW/cm<sup>2</sup> for 5 minutes (surface dose 5.4 J/cm<sup>2</sup>) at a working distance of 5 cm.
5. Postoperatively the patients were instructed to use
  - Topical gatifloxacin 3% eyedrops 4 times/day for 1 week.
  - Topical tobramycin 0.3%+dexamethasone 0.1% eyedrops 4 times/day for 1 week.
  - Topical artificial tears sodium hyaluronate 2% for 6 weeks.
  - Oral analgesics as required.
6. Follow-up examinations were performed on day 1, 3 and 7 postoperatively. Subsequent examinations were performed at 1, 3, 6, and 12 months postoperatively and then annually.

### **• Group IIB:**

1. Preoperative instillation of topical gatifloxacin eyedrops 3 times on the day of operation.
2. One drop of benoxinate HCL 0.4% was instilled every 5 minutes 3 times.
3. Photosensitizing solution (RICROLIN<sup>®</sup>TE- Transepithelial solution riboflavin 0.1%, dextran T500 15% + additive: sodium edetate, tromethamine, sodium phosphate dehydrate, NaCl (figure 22)) was then instilled every 2 minutes for 30 minutes.
4. The central cornea was exposed to an ultraviolet A source emanating from a solid-state device (CCL-365, Peschke GmbH (figure 23)), with a working wavelength of 370 nm at surface irradiance of 3 mW/cm<sup>2</sup> for 5 minutes (surface dose 5.4 J/cm<sup>2</sup>) at a working distance of 5 cm.
5. Postoperatively the patients were instructed to use
  - Topical gatifloxacin 3% eyedrops 4 times/day for 1 week.
  - Topical tobramycin 0.3%+dexamethasone 0.1% eyedrops 4 times/day for 1 week.
  - Topical artificial tears sodium hyaluronate 2% for 6 weeks.
  - Oral analgesics as required.
6. Follow-up examinations were performed on day 1, 3 and 7 postoperatively. Subsequent examinations were performed at 1, 3, 6, and 12 months postoperatively and then annually.



Figure 22 : Ricrolin TE riboflavin



Figure 23 : CCL-365 machine

• **Postoperatively, all patients were subjected to:**

1. Postoperative scheinplflug camera imaging (Pentacam HR, Oculus) after 1 month. In each eye keratometric values, minimal pachymetry, and KC level topography were compared to preoperative values.
2. Postoperative anterior segment optical coherence tomography was done after one month using the Spectralis HRA+OCT (Heidelberg Engineering, Inc.), a spectral-domain optical coherence tomography system that allows high-speed, high-resolution cross-sectional imaging, it obtains 40,000 A-scans per second. SD-OCT has a wavelength in the range of 820nm to 879nm. Using the L-Cam lens, a 6 mm long Hi-Res Cross Line Scan, centered at the pupil center along the vertical meridian, was recorded.
  - All images from both groups were investigated for possible quantitative evidence of changes induced by CXL. Evidence of such was considered as the existence of the intrastromal hyper-reflective demarcation line (figure 24).
  - CXL demarcation line depth was measured from the corneal epithelium to the detectable hyper-reflective demarcation line.
  - Corneal thickness was measured from the corneal epithelium to corneal endothelium.
  - Ratio of the CXL demarcation line depth to the corneal thickness was measured.

Measurements were taken at the corneal centre and at 1 and 2 mm from the corneal center in two locations: temporal and nasal. (Figure 25)

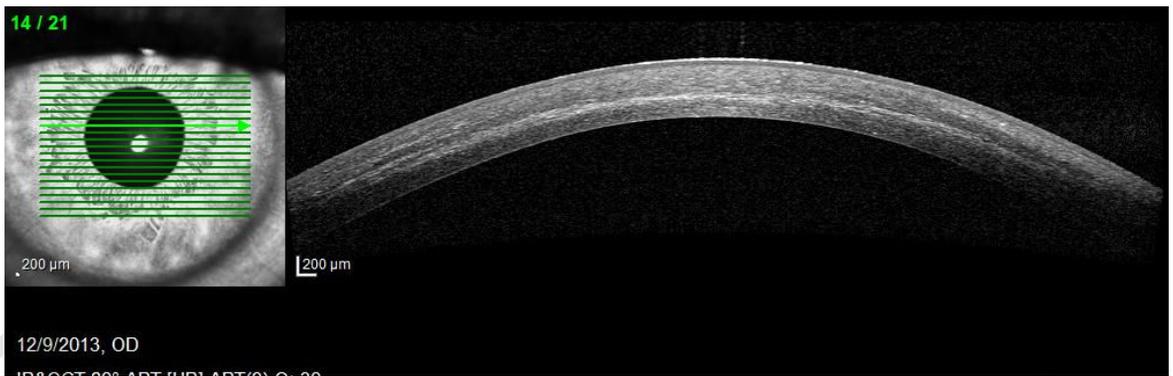


Figure 24: Demarcation line as shown by AS-OCT

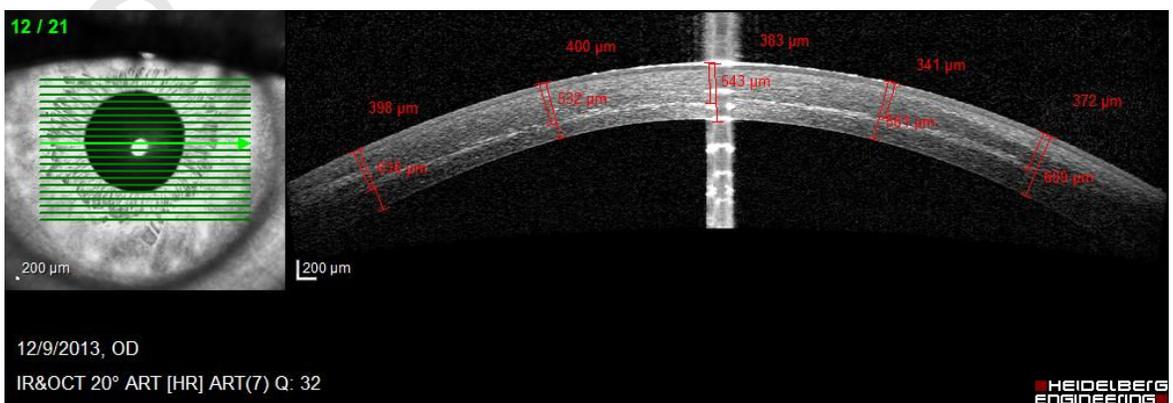


Figure 25: CXL demarcation line depth, corneal thickness measurement at the central cornea and at 1 and 2 mm from the corneal center in two locations: temporal and nasal.

## RESULTS

This study included 2 groups undergone CXL: group I (epithelium off) 20 eyes, and group II (transepithelium) subdivided into group IIA and group IIB each includes 10 eyes. All cases were followed up after 1 month using AS-OCT and pentacam.

### • Patient's demographic data:

Table II shows demographic data of patients in our study

**Table II: Distribution of the studied cases according to demographic data**

	Group I		Group IIA		Group IIB		Test of sig.	P
	No.	%	No.	%	No.	%		
<b>Sex</b>	(n = 10)		(n = 5)		(n = 5)		$\chi^2= 2.136$	MCp=0.381
Male	4	40.0	4	80.0	3	60.0		
Female	6	60.0	1	20.0	2	40.0		
<b>Age</b>	(n = 10)		(n = 5)		(n = 5)		F= 2.762	0.091
Min. – max.	15.0 – 31.0		13.0 – 29.0		20.0 – 35.0			
Mean $\pm$ SD.	23.10 $\pm$ 5.45		20.60 $\pm$ 6.07		29.20 $\pm$ 7.16			
Median	24.0		21.0		33.0			
<b>Eye</b>	(n = 20)		(n = 10)		(n = 10)		$\chi^2= 0.0$	1.000
OD	10	50.0	5	50.0	5	50.0		
OS	10	50.0	5	50.0	5	50.0		

$\chi^2$ : Chi square test

MC: Monte Carlo test

F: F test (ANOVA)

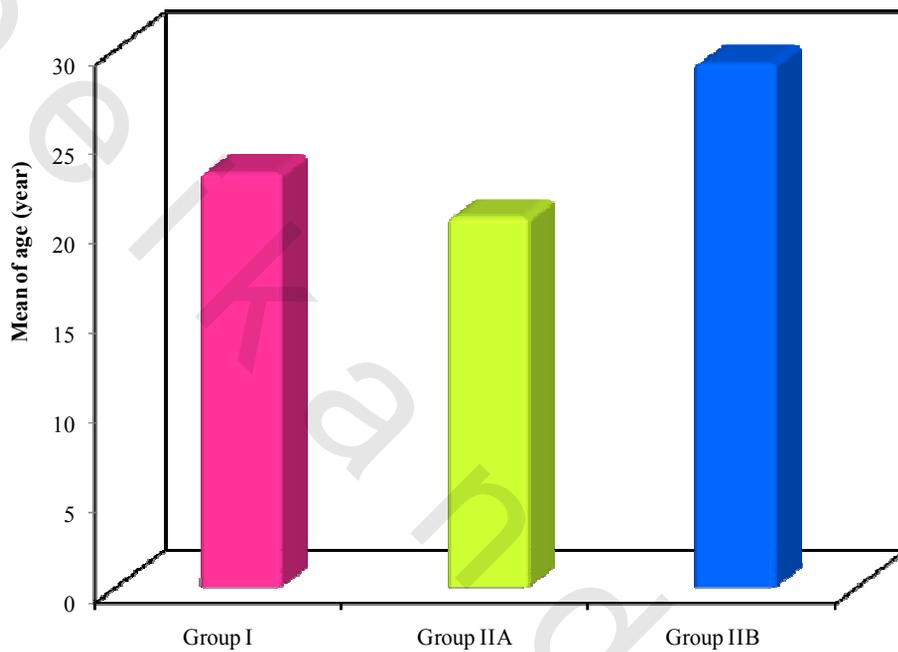
**Age:**

The mean age of group I patients was  $23.10 \pm 5.45$  with range from 15 to 31 years.

The mean age of group IIA patients was  $20.60 \pm 6.07$  with range from 13 to 29 years.

The mean age of group IIB patients was  $29.20 \pm 7.16$  with range from 20 to 35 years.

Graph 1 shows a comparison between the three studied groups according to age distribution.



**Graph 1: Comparison between the three studied groups according to age distribution**

**Sex:**

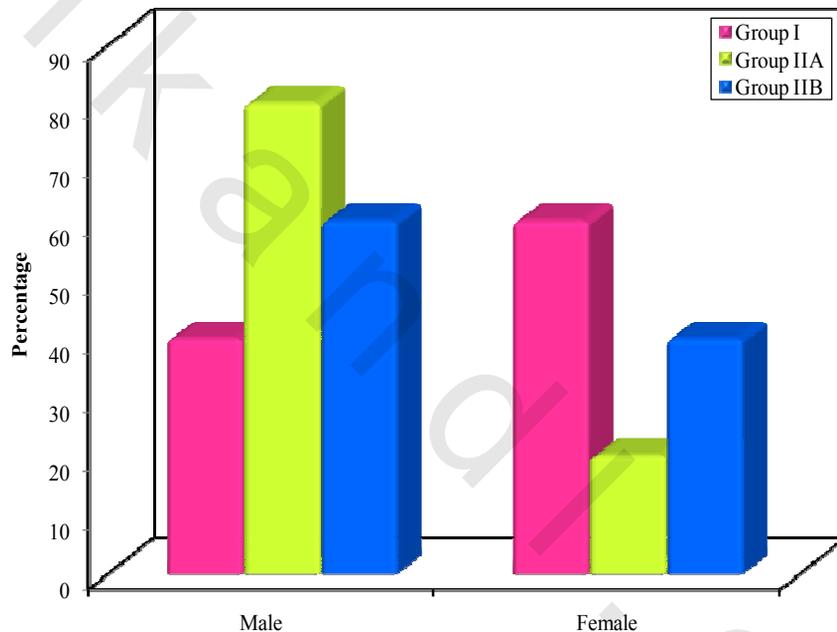
Number of male patients in Group I was 4 cases (8 eyes), while female patients represented 6 cases (12 eyes).

Number of male patients in Group IIA was 4 cases (8 eyes), while female patients represented 1 case (2 eyes).

Number of male patients in Group IIB was 3 cases (6 eyes), while female patients represented 2 cases (4 eyes).

Graph 2 shows a comparison between the three studied groups according to sex distribution.

All cases were bilateral; of the total 40 eyes, the distribution of right eyes and left eyes were balanced (20 eyes for each).



**Graph 2: Comparison between the three studied groups according to sex distribution**

- **OCT results:**

From the AS-OCT measurements, the following data were statistically analyzed:

### **Corneal stromal demarcation line depth (DLD):**

Table III shows a comparison between the three studied groups according to demarcation line depth.

Demarcation line was detected in all eyes of group I and group IIB patients while in group IIA, the line was not detected except in 2 eyes only (those undergone superficial scratches prior to riboflavin instillation).

Mean stromal demarcation line depth of group I was significantly deeper than that of group IIB at central and temporal location at 1 mm. No statistically different findings between group I and group IIB corneal stromal demarcation line depth at both nasal locations and temporal location at 2 mm.

In Group I, mean depth of the corneal stromal demarcation line (DLD) was  $254.25 \pm 76.23\mu\text{m}$  (range, 137.0 – 383.0 $\mu\text{m}$ ) centrally,  $247.30 \pm 78.78\mu\text{m}$  (range, 137.0 – 400.0 $\mu\text{m}$ ) temporally at 1mm,  $222.25 \pm 81.11\mu\text{m}$  (range, 137.0 – 398.0 $\mu\text{m}$ ) temporally at 2mm,  $255.80 \pm 82.19\mu\text{m}$  (range, 149.0 – 423.0 $\mu\text{m}$ ) nasally at 1mm, and  $223.0 \pm 78.30\mu\text{m}$  (range, 140.0 – 407.0 $\mu\text{m}$ ) nasally at 2mm.

In Group IIB, mean depth of the corneal stromal demarcation line (DLD) was  $198.20 \pm 48.99\mu\text{m}$  (range, 132.0 – 275.0 $\mu\text{m}$ ) centrally,  $202.30 \pm 33.77\mu\text{m}$  (range, 150.0 – 256.0 $\mu\text{m}$ ) temporally at 1mm,  $214.60 \pm 47.73$  (range, 132.0 – 286.0) temporally at 2mm,  $224.50 \pm 46.96\mu\text{m}$  (range, 148.0 – 286.0) nasally at 1mm, and  $240.50 \pm 68.91\mu\text{m}$  (range, 137.0 – 337.0 $\mu\text{m}$ ) nasally at 2mm.

Graph 3 shows a comparison between group I and IIB according to demarcation line depth.

**Table III : Comparison between the three studied groups according to demarcation line depth.**

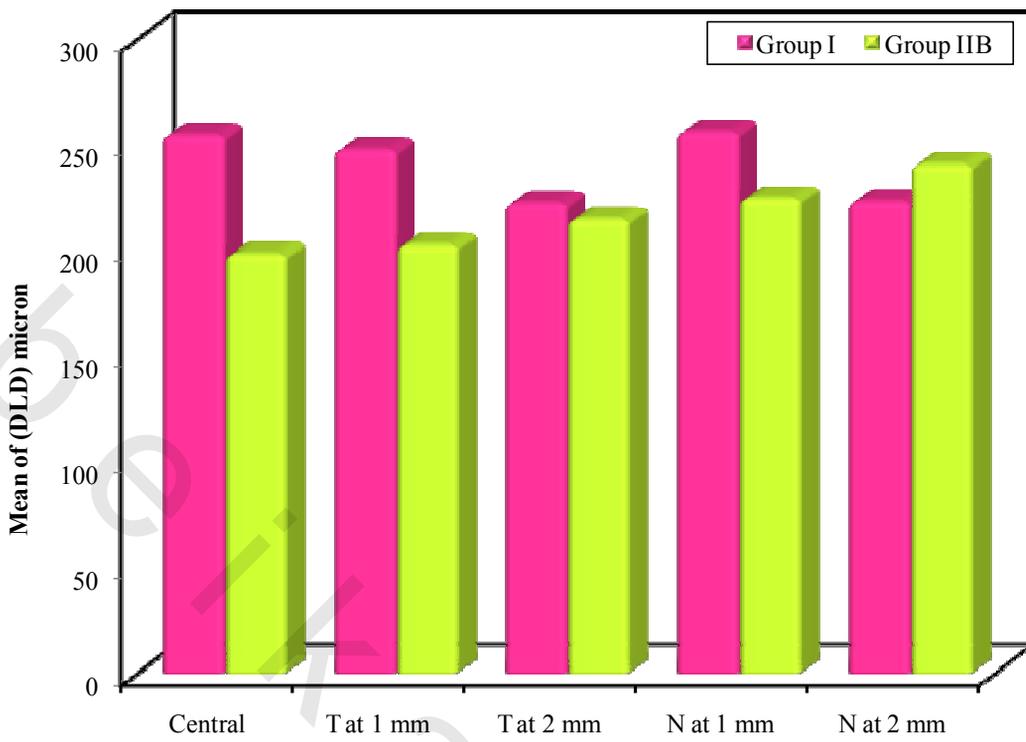
<b>(DLD) micron</b>	<b>Group I (n = 20)</b>	<b>Group IIA (n = 10)</b>	<b>Group IIB (n = 10)</b>	<b>T</b>	<b>P</b>
Central					
Min. – max.	137.0 – 383.0	ND	132.0 – 275.0		
Mean ± SD.	254.25 ± 76.23		198.20 ± 48.99	2.108*	0.044*
Median	253.50		201.50		
T at 1 mm					
Min. – max.	137.0 – 400.0	ND	150.0 – 256.0		
Mean ± SD.	247.30 ± 78.78		202.30 ± 33.77	2.185*	0.038*
Median	238.50		195.0		
T at 2 mm					
Min. – max.	137.0 – 398.0	ND	132.0 – 286.0		
Mean ± SD.	222.25 ± 81.11		214.60 ± 47.73	0.274	0.786
Median	194.0		219.0		
N at 1 mm					
Min. – max.	149.0 – 423.0	ND	148.0 – 286.0		
Mean ± SD.	255.80 ± 82.19		224.50 ± 46.96	1.111	0.276
Median	247.50		227.50		
N at 2 mm					
Min. – max.	140.0 – 407.0	ND	137.0 – 337.0		
Mean ± SD.	223.0 ± 78.30		240.50 ± 68.91	0.599	0.554
Median	197.50		235.0		

T: Student t-test

\*: Statistically significant at  $p \leq 0.05$

ND: Not detected

DLD results of the two eyes in group IIA undergone superficial scratches was 138 and 152  $\mu\text{m}$  centrally, 186 and 206  $\mu\text{m}$  temporally at 1mm, 245 and 228  $\mu\text{m}$  temporally at 2mm, 209 and 220  $\mu\text{m}$  nasally at 1mm, and 258 and 236  $\mu\text{m}$  nasally at 2mm.



**Graph 3: Comparison between group I and IIB according to demarcation line depth.**

### **Corneal thickness (CT):**

There was a statistically significant difference ( $P < 0.05$ ) between the corneal thicknesses of the three studied groups at all locations.

There was a statistically significant difference ( $P < 0.001$ ) between group I and group IIA corneal thickness at central, temporal locations and nasal location at 1 mm. At nasal location 2mm there was a statistically significant difference ( $P < 0.01$ ).

There was a statistically significant difference ( $P < 0.05$ ) between group I and group IIB corneal thickness at temporal region at 1mm and both nasal locations. At the central region there was a statistically significant difference ( $P < 0.01$ ).

In Group I, mean corneal thickness (CT) was  $494.10 \pm 44.89 \mu\text{m}$  (range, 420.0 – 601.0  $\mu\text{m}$ ) centrally,  $501.35 \pm 41.52 \mu\text{m}$  (range, 432.0 – 590.0  $\mu\text{m}$ ) temporally at 1mm,  $552.55 \pm 42.98 \mu\text{m}$  (range, 480.0 – 619.0  $\mu\text{m}$ ) temporally at 2mm,  $529.95 \pm 46.70 \mu\text{m}$  (range, 458.0 – 607.0  $\mu\text{m}$ ) nasally at 1mm, and  $597.05 \pm 57.02 \mu\text{m}$  (range, 488.0 – 695.0  $\mu\text{m}$ ) nasally at 2 mm.

In Group IIA, mean corneal thickness (CT) was  $413.40 \pm 33.70 \mu\text{m}$  (range, 380.0 – 492.0  $\mu\text{m}$ ) centrally,  $425.70 \pm 39.81 \mu\text{m}$  (range, 376.0 – 504.0  $\mu\text{m}$ ) temporally at 1mm,  $474.50 \pm 60.91 \mu\text{m}$  (range, 400.0 – 568.0  $\mu\text{m}$ ) temporally at 2mm,  $443.90 \pm 35.96 \mu\text{m}$  (range, 376.0 – 509.0) nasally at 1mm, and  $522.20 \pm 57.72 \mu\text{m}$  (range, 455.0 – 650.0  $\mu\text{m}$ ) nasally at 2 mm.

In Group IIB, mean corneal thickness (CT) was  $438.10 \pm 48.92 \mu\text{m}$  (range, 380.0 – 508.0  $\mu\text{m}$ ) centrally,  $454.0 \pm 48.52 \mu\text{m}$  (range, 370.0 – 520.0  $\mu\text{m}$ ) temporally at 1mm,  $508.50 \pm 48.62 \mu\text{m}$  (range, 508.50  $\pm 48.62 \mu\text{m}$ ) temporally at 2mm,  $484.80 \pm 24.28 \mu\text{m}$  (range, 449.0 - 520.0  $\mu\text{m}$ ) nasally at 1mm, and  $537.90 \pm 26.66 \mu\text{m}$  (range, 483.0 – 586.0) nasally at 2 mm.

Table IV shows a comparison between the three studied groups according to corneal thickness.

Graph 4 shows a comparison between the three studied groups according to corneal thickness.

**Table IV: Comparison between the three studied groups according to corneal thickness.**

(CT) micron	Group I (n = 20)	Group IIA (n = 10)	Group IIB (n = 10)	F	P
Central					
Min. – max.	420.0 – 601.0	380.0 – 492.0	380.0 – 508.0		
Mean ± SD.	494.10 ± 44.89	413.40 ± 33.70	438.10 ± 48.92	13.144*	<0.001*
Median	499.0	401.50	430.50		
Sig. bet. Groups	I-IIA***, I-IIB**				
T at 1 mm					
Min. – max.	432.0 – 590.0	376.0 – 504.0	370.0 – 520.0		
Mean ± SD.	501.35 ± 41.52	425.70 ± 39.81	454.0 ± 48.52	11.347*	<0.001*
Median	500.50	414.50	454.0		
Sig. bet. Groups	I-IIA***, I-IIB*				
T at 2 mm					
Min. – max.	480.0 – 619.0	400.0 – 568.0	422.0 – 577.0		
Mean ± SD.	552.55 ± 42.98	474.50 ± 60.91	508.50 ± 48.62	8.873*	0.001*
Median	545.0	459.0	504.0		
Sig. bet. Groups	I-IIA***				
N at 1 mm					
Min. – max.	458.0 – 607.0	376.0 – 509.0	449.0 - 520.0		
Mean ± SD.	529.95 ± 46.70	443.90 ± 35.96	484.80 ± 24.28	16.284*	<0.001*
Median	540.0	439.0	481.0		
Sig. bet. Groups	I-IIA***, I-IIB*				
N at 2 mm					
Min. – max.	488.0 – 695.0	455.0 – 650.0	483.0 – 586.0		
Mean ± SD.	597.05 ± 57.02	522.20 ± 57.72	537.90 ± 26.66	8.693*	0.001*
Median	606.50	507.50	542.0		
Sig. bet. Groups	I-IIA**, I-IIB*				

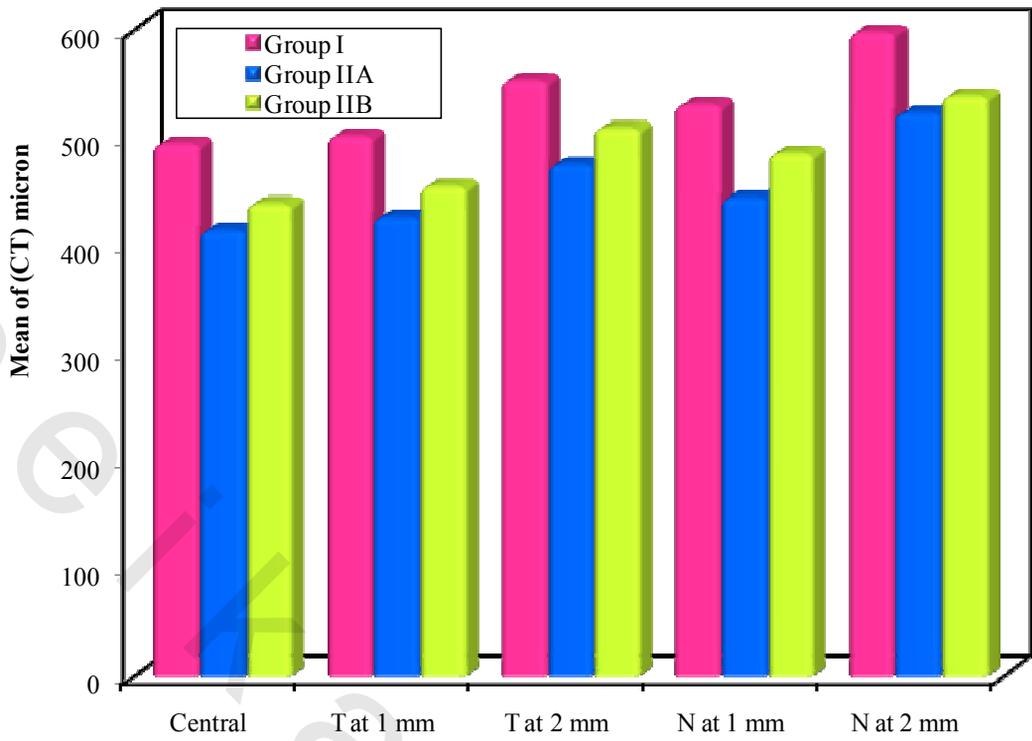
F: F test (ANOVA)

Sig. bet. grps was done using Post Hoc Test (Scheffe)

\*: Statistically significant at  $p \leq 0.05$

\*\*: Statistically significant at  $p \leq 0.01$

\*\*\*: Statistically significant at  $p \leq 0.001$



**Graph 4 : Comparison between the three studied groups according to corneal thickness(micron).**

### **Corneal stromal demarcation line depth to corneal thickness ratio (DLD/CT):**

Table V shows a comparison between the three studied groups according to demarcation line depth to corneal thickness ratio.

There was no statistically significant difference between group I and group IIB corneal stromal demarcation line depth to corneal thickness ratio at all locations. In Group IIA, the ratio could not be measured.

In Group I, the ratio was  $0.51 \pm 0.16\%$  (range, 0.27 – 0.74%) centrally,  $0.49 \pm 0.15\%$  (range, 0.26 – 0.75%) temporally at 1mm,  $0.40 \pm 0.12\%$  (range, 0.24 – 0.65%) temporally at 2mm,  $0.49 \pm 0.15\%$  (range, 0.26 – 0.75%) nasally at 1mm, and  $0.37 \pm 0.12\%$  (range, 0.23 – 0.61%) nasally at 2mm.

In Group IIB, the ratio was  $0.45 \pm 0.10\%$  (range, 0.30 – 0.64%) centrally,  $0.45 \pm 0.10\%$  (range, 0.33 – 0.69%) temporally at 1mm,  $0.42 \pm 0.09\%$  (range, 0.28 – 0.50%) temporally at 2mm,  $0.46 \pm 0.10\%$  (range, 0.32 – 0.60%) nasally at 1mm, and  $0.44 \pm 0.11\%$  (range, 0.28 – 0.61%) nasally at 2mm.

Graph 5 shows a comparison between the two studied groups according to demarcation line depth to corneal thickness ratio.

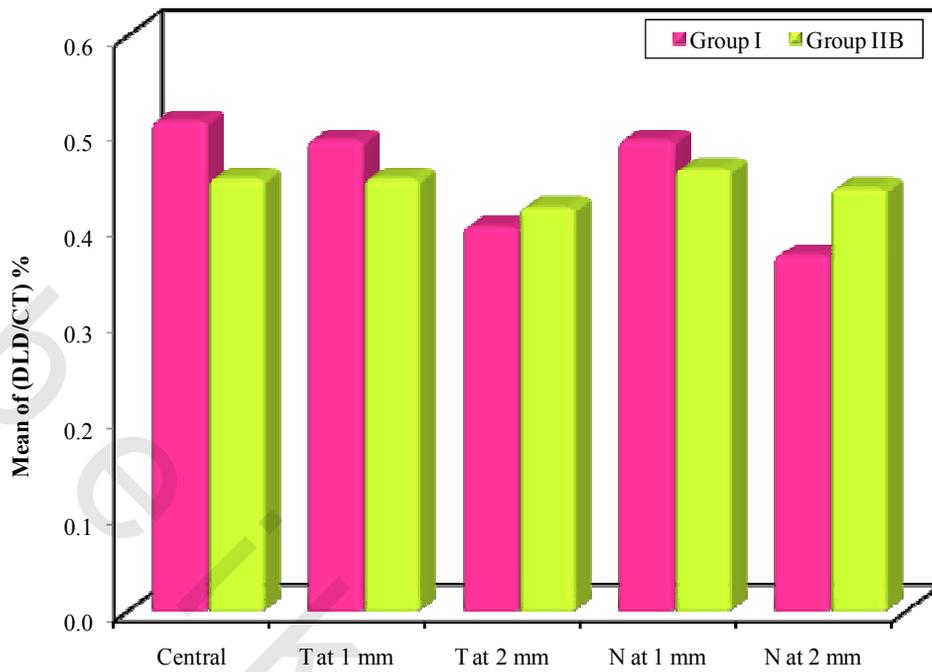
**Table V : Comparison between the three studied groups according to demarcation line depth to corneal thickness ratio**

<b>(DLD/CT) %</b>	<b>Group I (n = 20)</b>	<b>Group IIA (n = 10)</b>	<b>Group IIB (n = 10)</b>	<b>T</b>	<b>P</b>
Central					
Min. – max.	0.27 – 0.74		0.30 – 0.64		
Mean ± SD.	0.51 ± 0.16	ND	0.45 ± 0.10	1.236	0.228
Median	0.50		0.46		
T at 1 mm					
Min. – max.	0.26 – 0.75		0.33 – 0.69		
Mean ± SD.	0.49 ± 0.15	ND	0.45 ± 0.10	0.826	0.416
Median	0.50		0.46		
T at 2 mm					
Min. – max.	0.24 – 0.65		0.28 – 0.50		
Mean ± SD.	0.40 ± 0.12	ND	0.42 ± 0.09	0.500	0.621
Median	0.37		0.46		
N at 1 mm					
Min. – max.	0.26 – 0.75		0.32 – 0.60		
Mean ± SD.	0.49 ± 0.15	ND	0.46 ± 0.10	0.457	0.651
Median	0.50		0.47		
N at 2 mm					
Min. – max.	0.23 – 0.61		0.28 – 0.61		
Mean ± SD.	0.37 ± 0.12	ND	0.44 ± 0.11	1.621	0.116
Median	0.34		0.44		

T: Student t-test

ND: Not detected

DLD/CT ratio results of the two eyes in group IIA undergone superficial scratches was 0.32 and 0.39% centrally, 0.4 and 0.46% temporally at 1mm, 0.45 and 0.47 % temporally at 2mm, 0.44 and 0.49% nasally at 1mm, and 0.48 and 0.45% nasally at 2mm.



Graph 5: Comparison between group I and IIB according to demarcation line depth to corneal thickness ratio

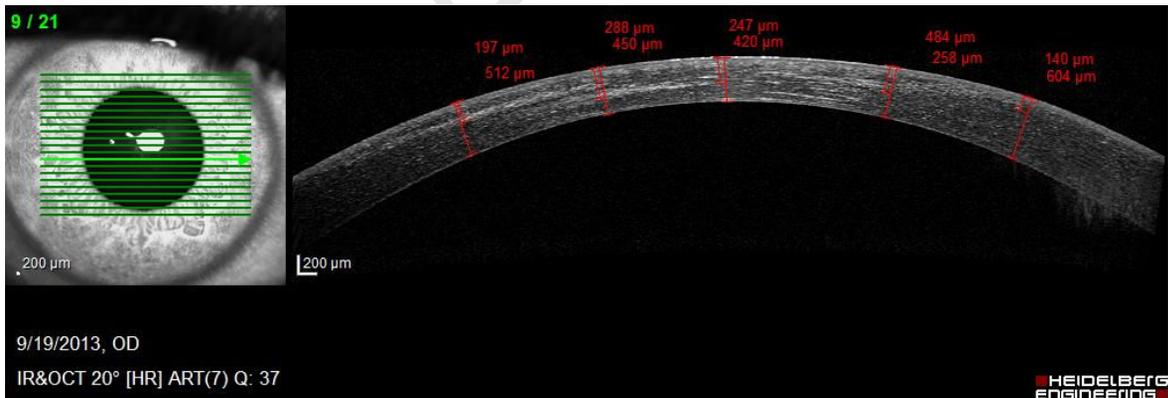


Figure 26: AS-OCT shows stromal demarcation line of one eye of group I patients

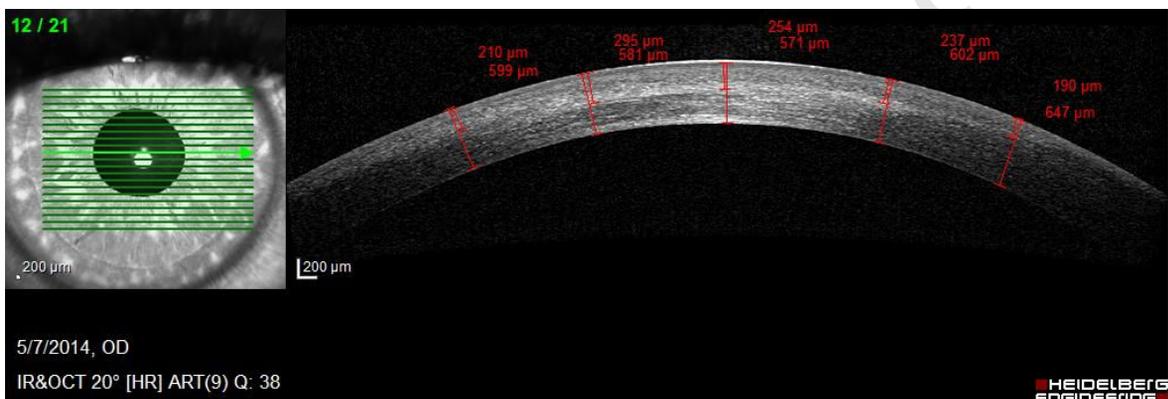


Figure 27: AS-OCT shows stromal demarcation line of one eye of group I patients

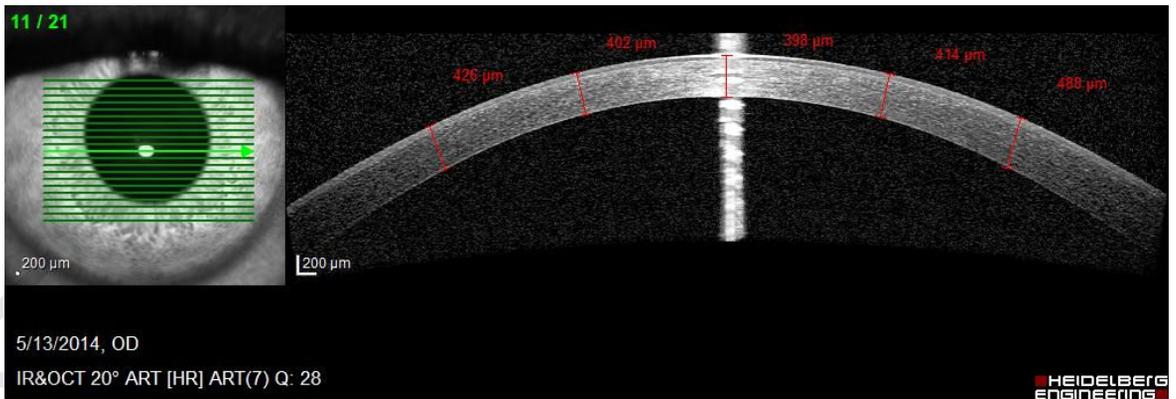


Figure 28: AS-OCT shows no demarcation line in group IIA

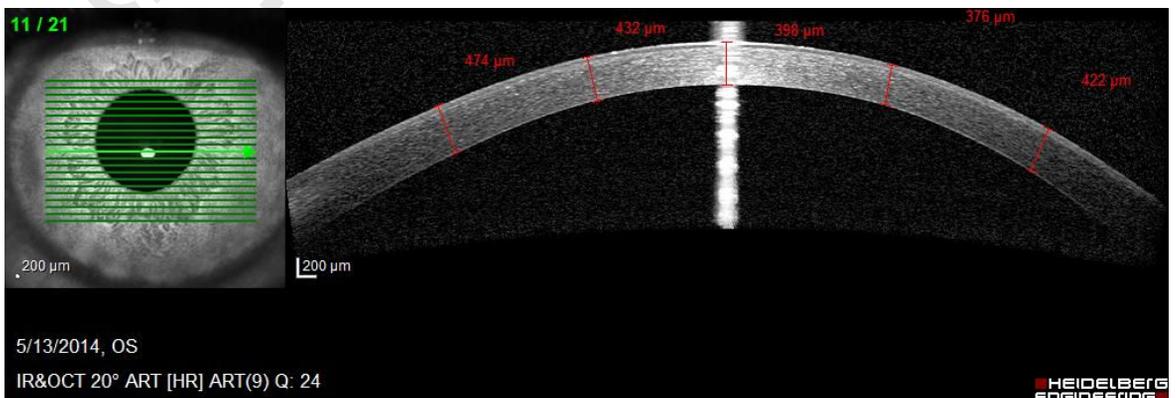


Figure 29: AS-OCT shows no demarcation line in group IIA

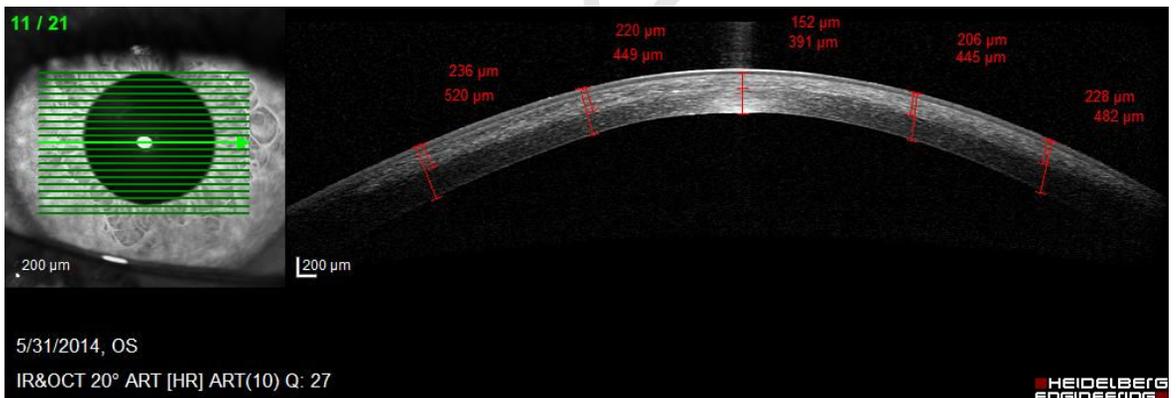


Figure 30: AS-OCT shows demarcation line in one of the eyes undergone superficial scratches in group IIA

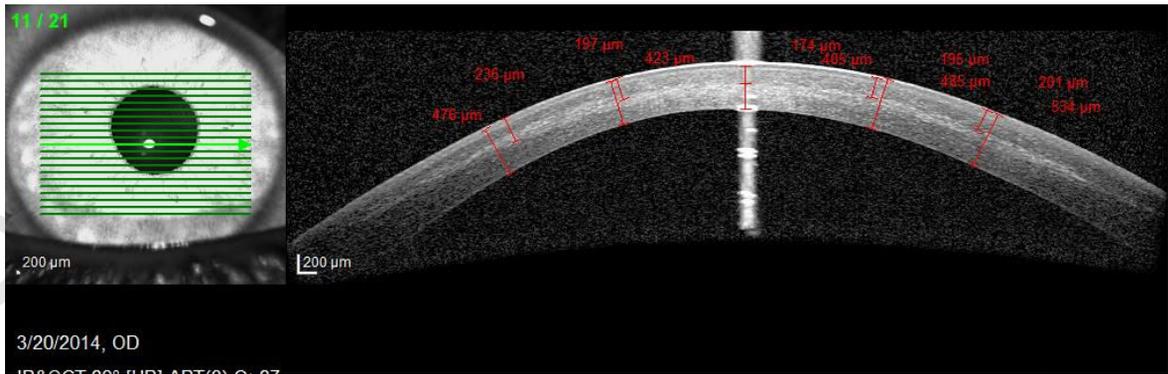


Figure 31: AS-OCT shows demarcation line in one eye of group IIB patients

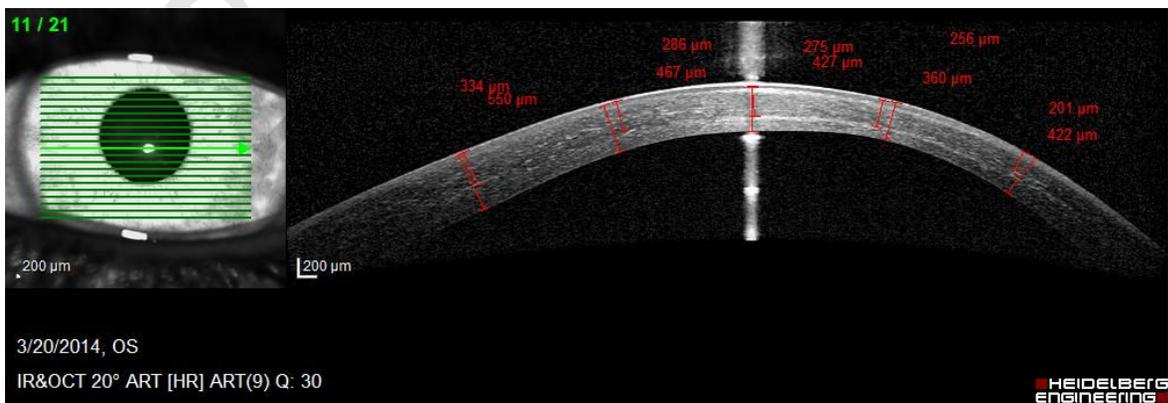


Figure 32: AS-OCT shows demarcation line in one eye of group IIB patients

- **Pentacam results**

From the refractive map of pentacam, the postoperative data obtained after one month were compared to the preoperative data and the following data were statistically analyzed.

**K1:**

Table VI compares preoperative and postoperative K1 values in the three studied groups. We detected a minimal decrease (flattening) in postoperative mean K1 values of group I and group IIA, and a minimal increase (steepening) in postoperative mean K1 values of group IIB which was not statistically significant.

No statistically significant difference between the three studied groups according to K1 change.

In group I mean K1 was  $44.53 \pm 3.27D$  in the preoperative period with a range between  $39.80 - 51.8D$ . Postoperative K1 range was between  $35.40 - 52.20 D$  with a mean of  $43.86 \pm 4.89 D$ .

In group IIA mean K1 was  $48.66 \pm 5.61D$  in the preoperative period with a range between  $41.30 - 58.50 D$ . Postoperative K1 range was between  $41.40-57.40 D$  with a mean of  $48.40 \pm 5.74D$ .

In group IIB mean K1 was  $47.28 \pm 5.37D$  in the preoperative period with a range between  $41.90 - 57.10 D$ . Postoperative K1 range was between  $42.70-57.50 D$  with a mean of  $47.58 \pm 5.38D$ .

Graph 6 shows a comparison between the three studied groups according to K1 while graph 7 shows a comparison between the three studied groups according preoperative and postoperative K1 change.

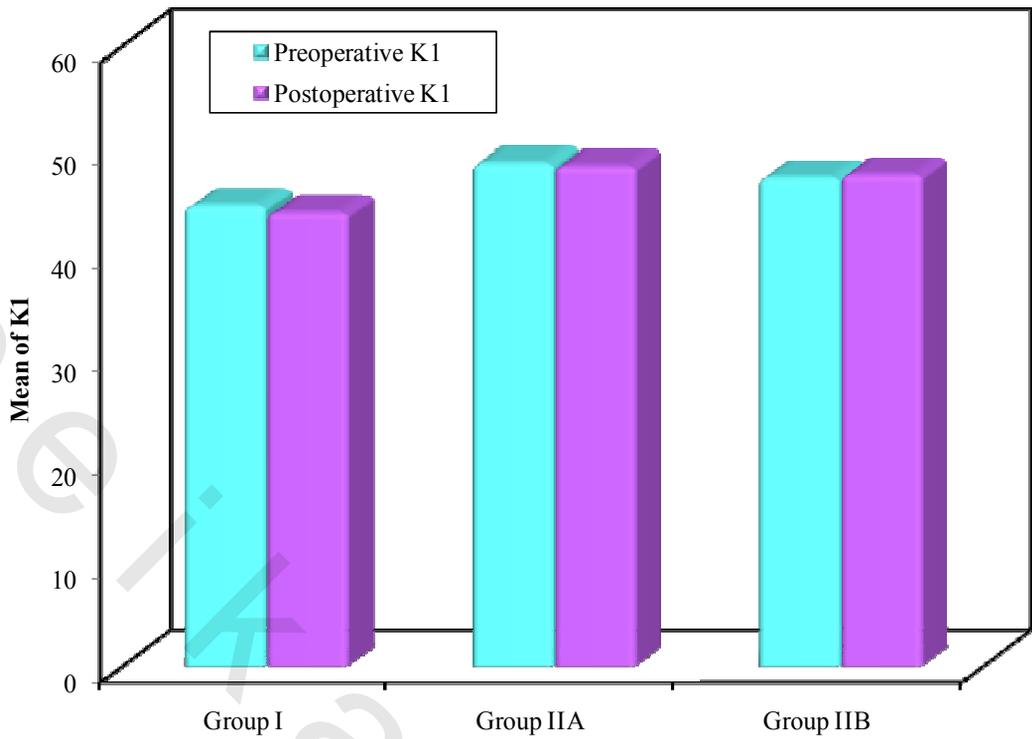
**Table VI: Comparison between preoperative and postoperative measurements according to K1 in the three studied groups**

	<b>Group I (n = 12)</b>	<b>Group IIA (n = 10)</b>	<b>Group IIB (n = 10)</b>	<b>Test of sig.</b>	<b>P</b>
Preoperative K1					
Min. – Max.	39.80 – 51.80	41.30 – 58.50	41.90 – 57.10		
Mean ± SD	44.53 ± 3.27	48.66 ± 5.61	47.28 ± 5.37	F= 2.164	0.133
Median	43.45	47.20	45.80		
Postoperative K1					
Min. – Max.	35.40 – 52.20	41.40 – 57.40	42.70 – 57.50		
Mean ± SD	43.86 ± 4.89	48.40 ± 5.74	47.58 ± 5.38	F= 2.321	0.116
Median	43.65	47.45	46.65		
p2	0.466	0.495	0.169		
Change					
Min. – Max.	-7.10 – 2.70	-3.10 – 0.50	-0.60 – 1.40		
Mean ± SD	-0.67 ± 3.06	-0.26 ± 1.15	0.29 ± 0.61	KW $\chi^2$ = 1.038	0.595
Median	0.20	0.20	0.35		

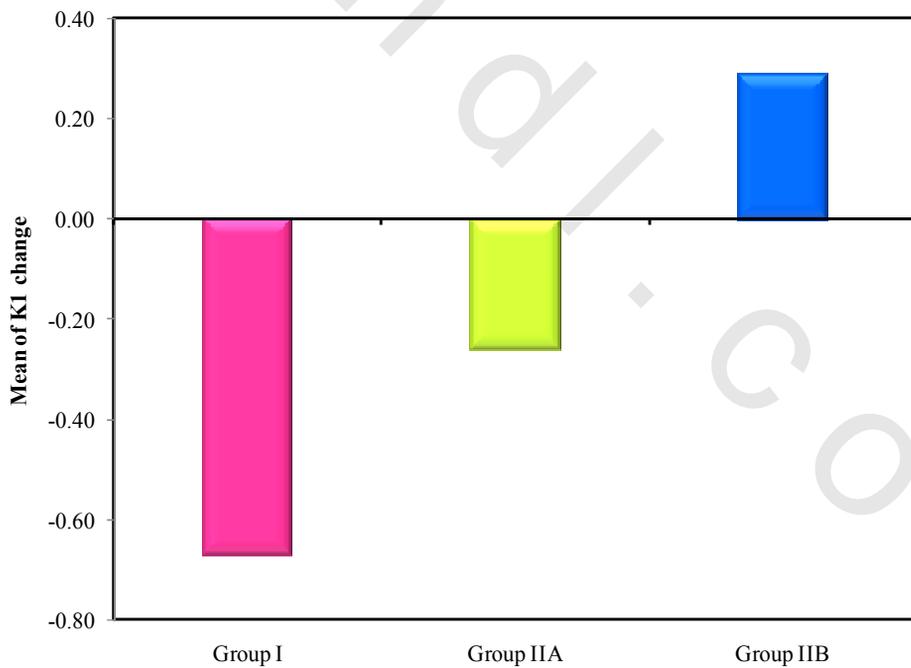
F: F test (ANOVA)

KW: Kruskal Wallis test

p2: p value for Paired t-test for comparing between preoperative k1 and postoperative k1 in each studied group



**Graph 6: Comparison between the three studied groups according to K1**



**Graph 7: Comparison between the three studied groups according to K1 change**

**K2:**

Table VII compares preoperative and postoperative K2 values in the three studied groups. We detected a minimal decrease (flattening) in postoperative mean K2 values of group I and group IIA, and a minimal increase (steepening) in postoperative mean K2 values of group IIB which was not statistically significant.

There was statistically significant difference between group I and IIA and between the three studied groups as regards preoperative and postoperative K2 values at  $p \leq 0.05$ .

There was no statistically significant difference between the three studied groups according to K2 change.

In group I mean K2 was  $47.09 \pm 3.69$ D in the preoperative period with a range between 40.70-55.10 D. Postoperative K2 range was between 40.10-55.30 D with a mean of  $46.32 \pm 4.65$ D.

In group IIA mean K2 was  $54.66 \pm 7.48$  D in the preoperative period with a range between 45.30-66.40 D. Postoperative K2 range was between 42.40-66.30 D with a mean of  $54.62 \pm 8.14$  D.

In group IIB mean K2 was  $51.06 \pm 6.08$  D in the preoperative period with a range between 45.50-60.10 D. Postoperative K2 range was between 46.50-61.0 D with a mean of  $51.44 \pm 5.81$ D.

Graph 8 shows a comparison between the three studied groups according to K2 while graph 9 shows a comparison between the three studied groups according preoperative and postoperative K2 change.

**Table VII: Comparison between preoperative and postoperative measurements according to K2 in the three studied groups**

	<b>Group I (n = 12)</b>	<b>Group IIA (n = 10)</b>	<b>Group IIB (n = 10)</b>	<b>Test of sig.</b>	<b>P</b>
Preoperative K2					
Min. – Max.	40.70 – 55.10	45.30 – 66.40	45.50 – 60.10		
Mean ± SD	47.09 ± 3.69	54.66 ± 7.48	51.06 ± 6.08	F= 4.621*	0.018*
Median	46.60	55.10	47.40		
Sig. bet. Grps	I-IIA*				
Postoperative K2					
Min. – Max.	40.10 – 55.30	42.40 – 66.30	46.50 – 61.0		
Mean ± SD	46.32 ± 4.65	54.62 ± 8.14	51.44 ± 5.81	F= 4.952*	0.014*
Median	46.35	55.70	47.55		
Sig. bet. Grps	I-IIA*				
p2	0.403	0.913	0.078		
Change					
Min. – Max.	-7.30 – 2.0	-2.90 – 1.10	-0.60 – 1.10		
Mean ± SD	-0.78 ± 3.08	-0.4 – 1.13	0.38 – 0.60	KW $\chi^2$ = 0.640	0.726
Median	0.25	0.35	0.45		

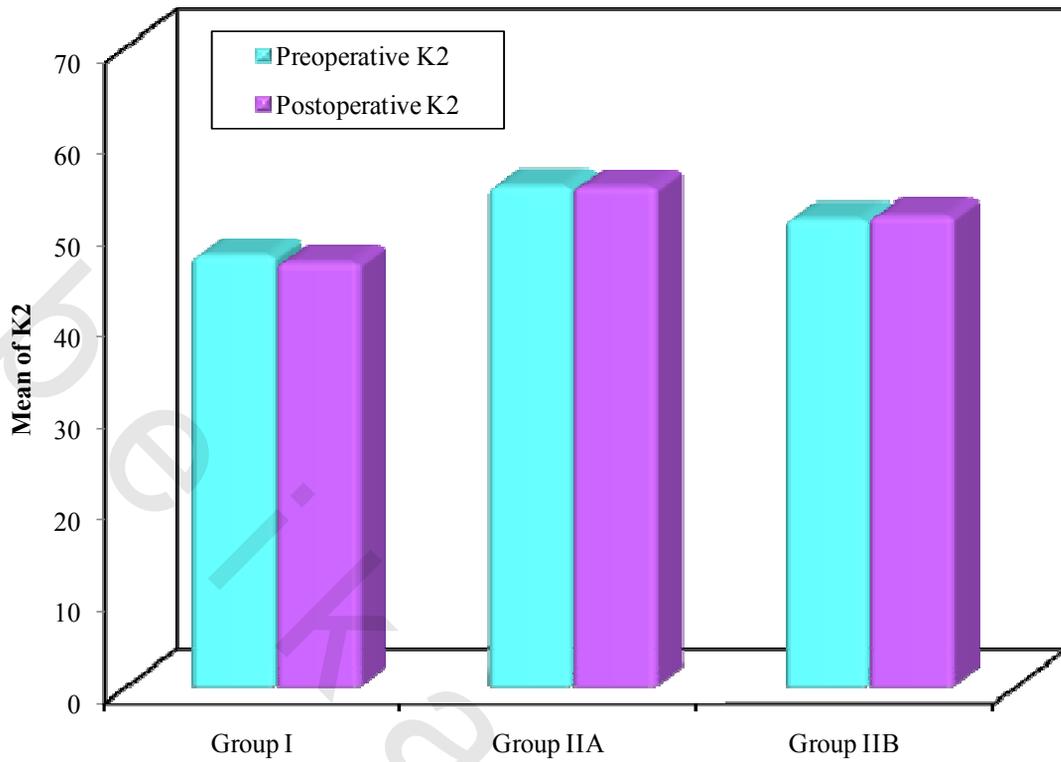
F: F test (ANOVA)

KW: Kruskal Wallis test

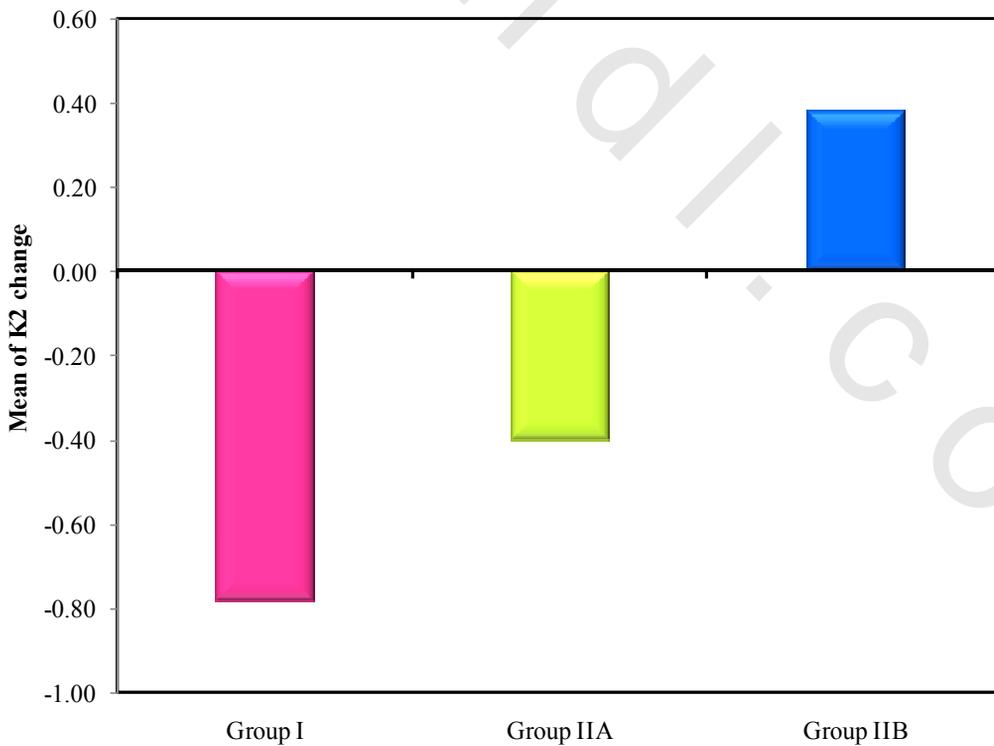
Sig. bet. grps was done using Post Hoc Test (Scheffe)

p2: p value for Paired t-test for comparing between pre and post in each studied group

\*: Statistically significant at  $p \leq 0.05$



**Graph 8: Comparison between the three studied groups according to K2**



**Graph 9: Comparison between the three studied groups according to K2 change**

## **Pachymetry:**

Using pentacam , pachymetry was measured at thinnest location for all patients in the three studied groups as demonstrated in table VIII. Group I showed a significant decrease in the postoperative thinnest location while group IIA and IIB showed a non significant decrease. There was statistically significant difference between group I and IIA and between group I and IIB as regards preoperative and postoperative thinnest location at  $p \leq 0.001$ .

There was statistically significant difference between group I and IIA at  $p \leq 0.05$  as regards preoperative and postoperative thinnest location change, and between group I and IIB at  $p \leq 0.01$ .

In group I preoperative thinnest location mean pachymetry was  $521.50 \pm 49.40$  ranging from 466.0 – 596.0. There was a statistical significant difference existed between pre operative and postoperative pachymetry, postoperative corneal thickness ranged from 463.0 – 573.0 with a mean of  $501.83 \pm 36.10$ .

In group IIA preoperative thinnest location mean pachymetry was  $411.80 \pm 34.24$  ranging from 376.0 – 473.0. No statistical significant difference existed between pre operative and postoperative pachymetry, postoperative corneal thickness ranged from 372.0 – 462.0 with a mean of  $404.20 \pm 26.28$ .

In group IIB preoperative thinnest location mean pachymetry was  $418.10 \pm 48.57$  ranging from 371.0 – 510.0. No statistical significant difference existed between pre operative and postoperative pachymetry, postoperative corneal thickness ranged from 370.0 – 508.0 with a mean of  $416.10 \pm 48.76$ .

Graph 10 shows a comparison between the three studied groups according to pachymetry thinnest location while graph 11 shows a comparison between the three studied groups according preoperative and postoperative pachymetry thinnest location change.

**Table VIII : Comparison between preoperative and postoperative pachymetry thinnest location in the three studied groups.**

Thin location	Group I (n = 12)	Group IIA (n = 10)	Group IIB (n = 10)	Test of sig.	P
Preoperative					
Min. – Max.	466.0 – 596.0	376.0 – 473.0	371.0 – 510.0		
Mean ± SD	521.50 ± 49.40	411.80 ± 34.24	418.10 ± 48.57	F=21.107*	<0.001*
Median	503.50	402.50	401.0		
Sig. bet. Grps	I-IIA***, I-IIB***				
Postoperative					
Min. – Max.	463.0 – 573.0	372.0 – 462.0	370.0 – 508.0		
Mean ± SD	501.83 ± 36.10	404.20 ± 26.28	416.10 ± 48.76	22.035*	<0.001*
Median	495.0	394.50	399.0		
Sig. bet. Grps	I-IIA***, I-IIB***				
p2	0.008*	0.163	0.163		
Change					
Min. – Max.	-65.0 - -1.0	-48.0 – 4.0	-10.0 – 7.0		
Mean ± SD	-19.67 ± 20.90	-7.60 ± 15.80	-2.0 – 4.16	KW $\chi^2$ = 8.818*	0.012*
Median	-12.50	-3.0	-2.0		
Sig. bet. Grps	I-IIA*, I-IIB**				

F: F test (ANOVA)

KW: Kruskal Wallis test

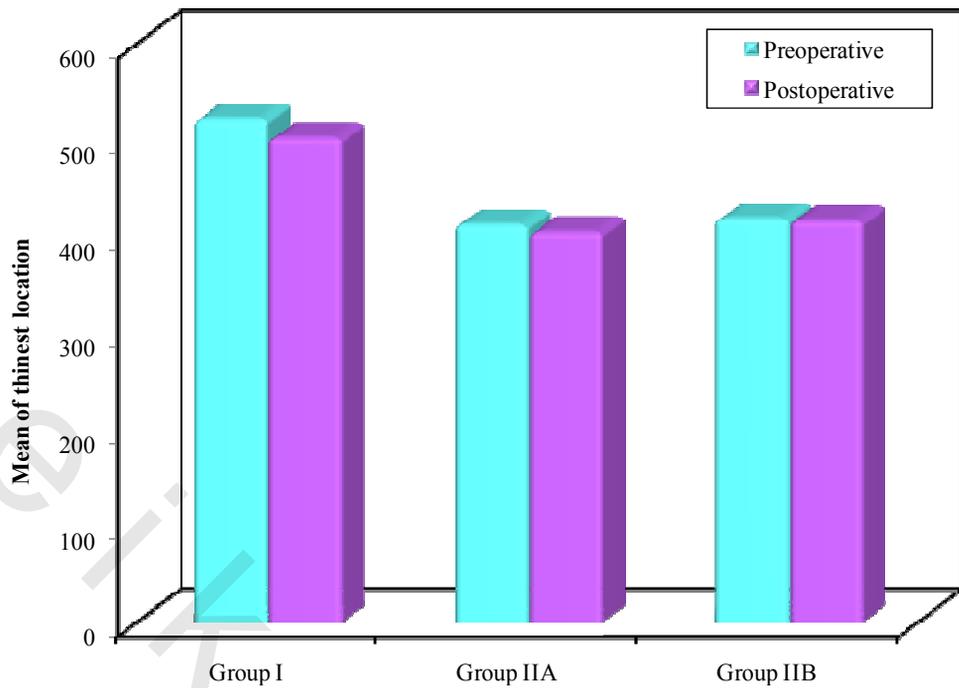
Sig. bet. grps was done using Post Hoc Test (Scheffe) or Mann Whitney test

p2: p value for Paired t-test for comparing between pre and post in each studied group

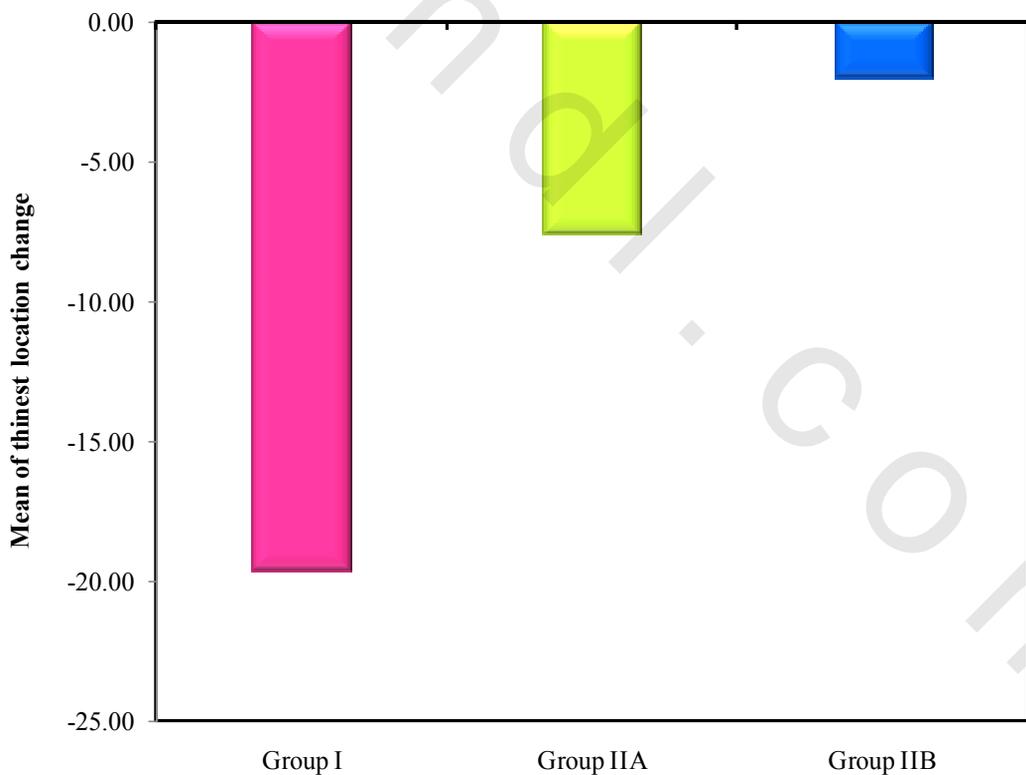
\*: Statistically significant at  $p \leq 0.05$

\*\*: Statistically significant at  $p \leq 0.01$

\*\*\*: Statistically significant at  $p \leq 0.001$



**Graph 10:** Comparison between the three studied groups according to preoperative and postoperative pachymetry thinnest location



**Graph 11:** Comparison between the three studied groups according to pachymetry thinnest location change

**Amsler-Krumeich keratoconus classification:**

Table IX shows a comparison between preoperative and postoperative KC level in the three groups according to Amsler-Krumeich keratoconus classification.

In group I the percentage of preoperative and postoperative pre-stage cases and those between KC level 3 and 4 were the same 35% and 10% respectively, while percentage of KC level between 1 and 2 decreased from 25% to 15% and those between 2 and 3 increased from 30% to 40%.

In group IIA and IIB the preoperative and postoperative percentages of all KC levels remained the same.

**Table IX : Comparison between preoperative and postoperative KC level in the three groups according to Amsler-Krumeich keratoconus classification**

KC	Group I (n = 20)		Group IIA (n = 10)		Group IIB (n = 10)	
	No.	%	No.	%	No.	%
Preoperative						
Pre-stage	7	35.0	1	10.0	0	0.0
1 – 2	5	25.0	1	10.0	4	40.0
2 – 3	6	30.0	6	60.0	4	40.0
3 – 4	2	10.0	2	20.0	2	20.0
Postoperative						
Pre-stage	7	35.0	1	10.0	0	0.0
1 – 2	3	15.0	1	10.0	4	40.0
2 – 3	8	40.0	6	60.0	4	40.0
3 – 4	2	10.0	2	20.0	2	20.0

WAVELIGHT - ALLEGRO OCULYZER

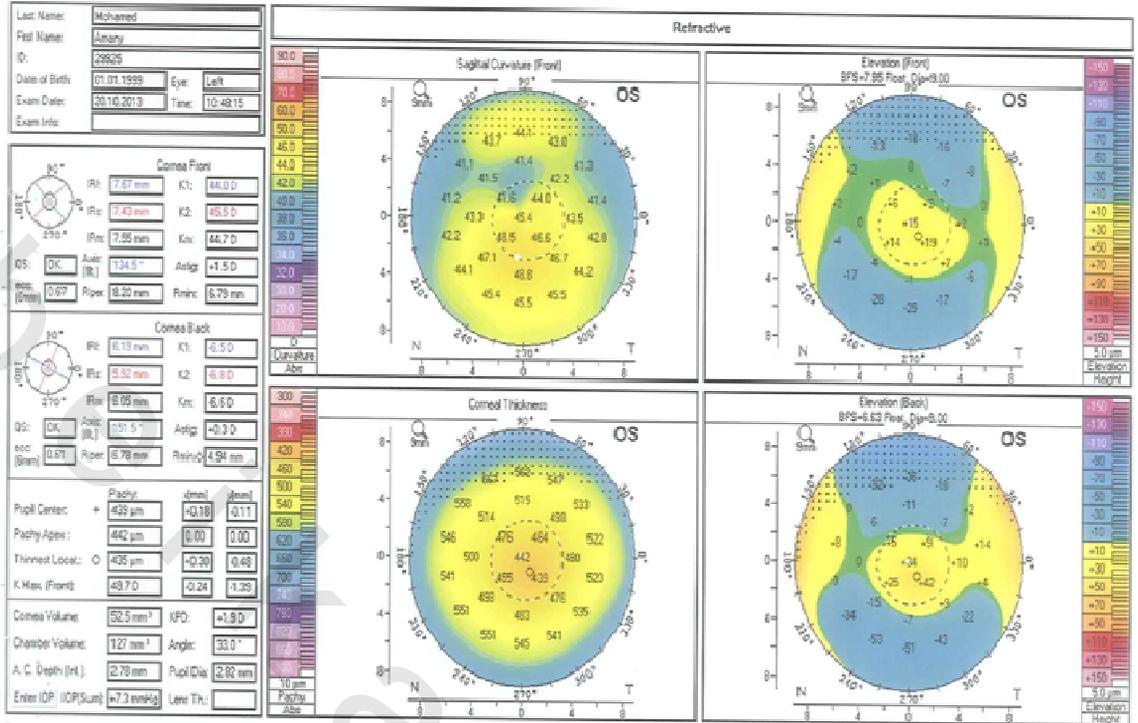


Figure 33: Preoperative pentacam of one eye of group I cases

WAVELIGHT - ALLEGRO OCULYZER

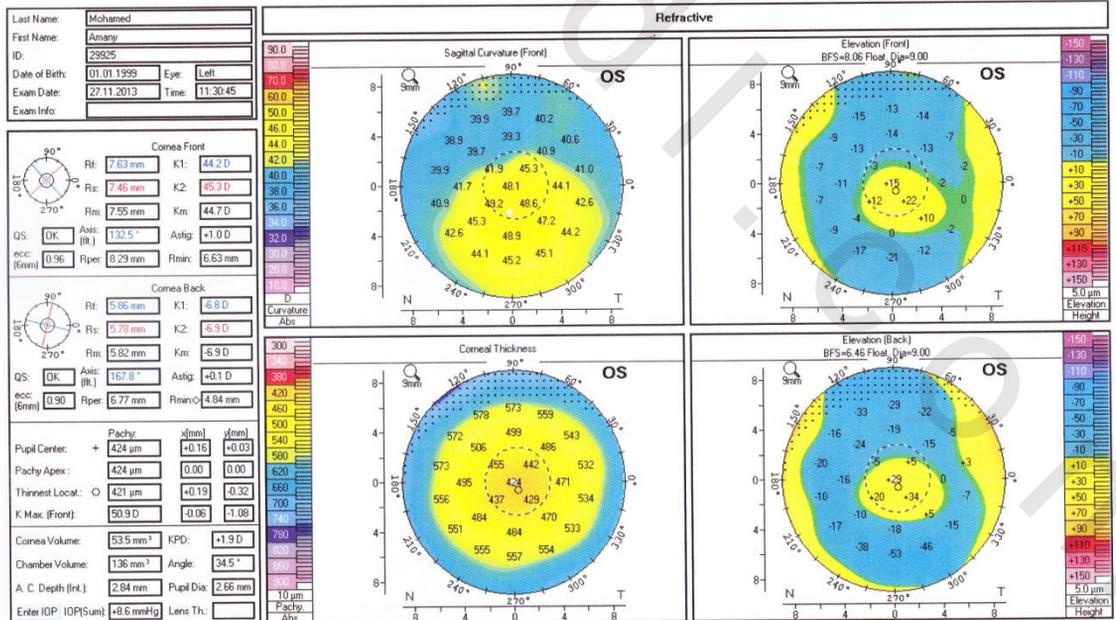


Figure 34: Postoperative pentacam of one eye of group I cases

WAVELIGHT - ALLEGRO OCULYZER

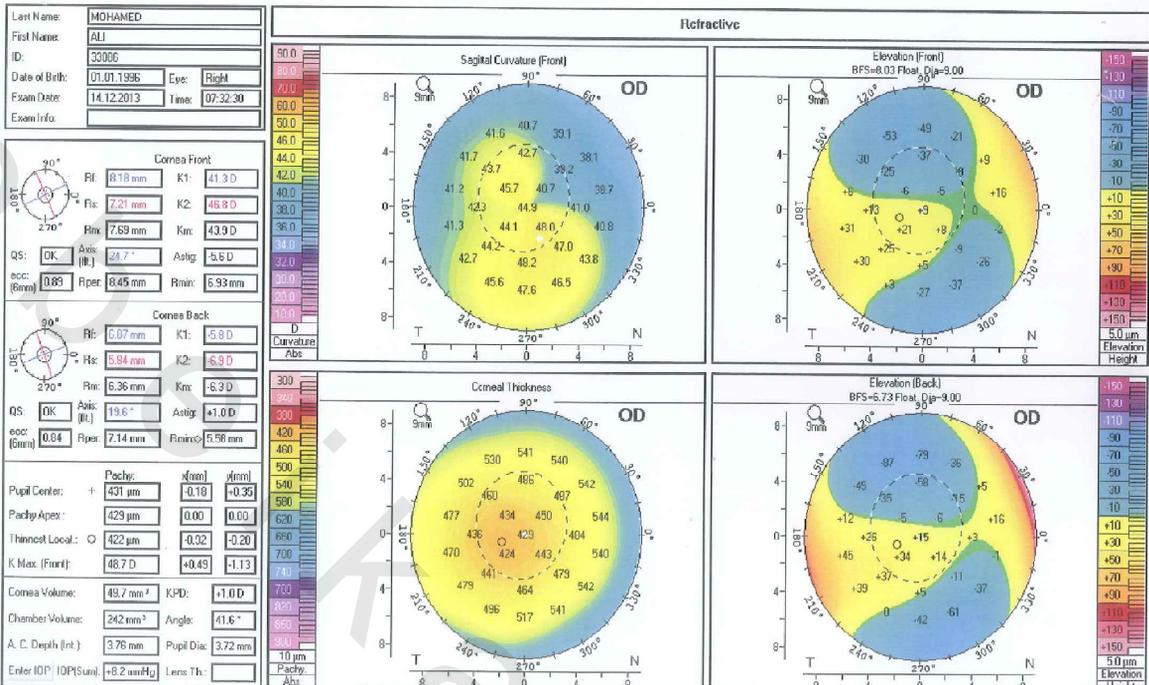


Figure 35: Preoperative pentacam of one eye of group IIA cases

WAVELIGHT - ALLEGRO OCULYZER

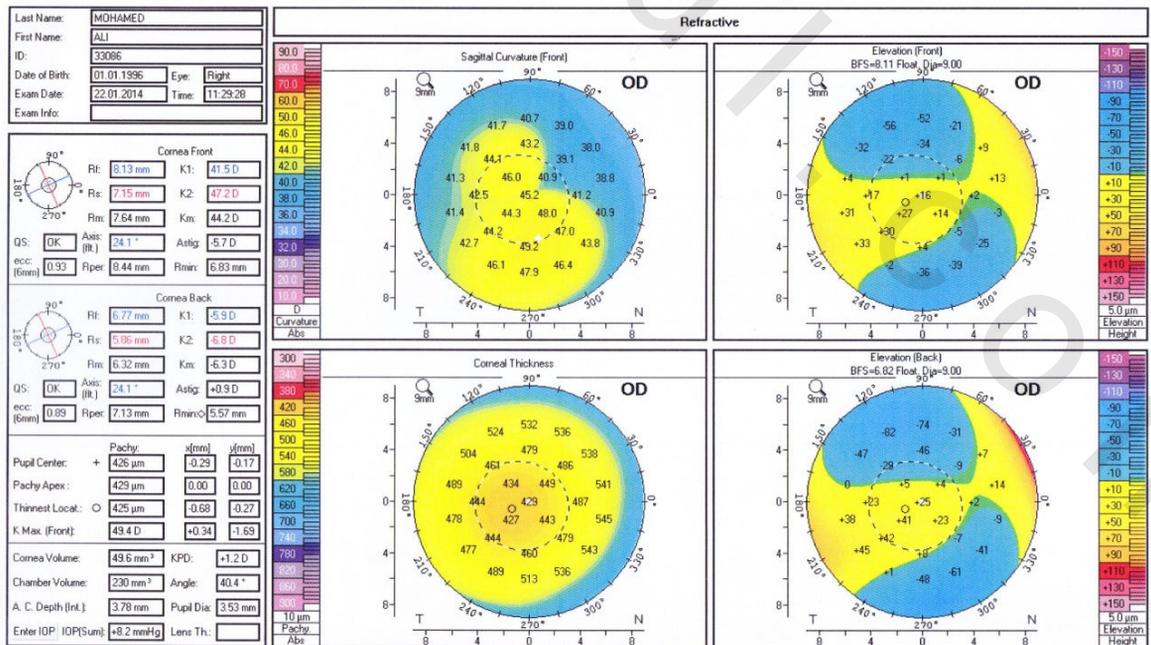


Figure 36: Postoperative pentacam of one eye of group IIA cases

WAVELIGHT - ALLEGRO OCULYZER

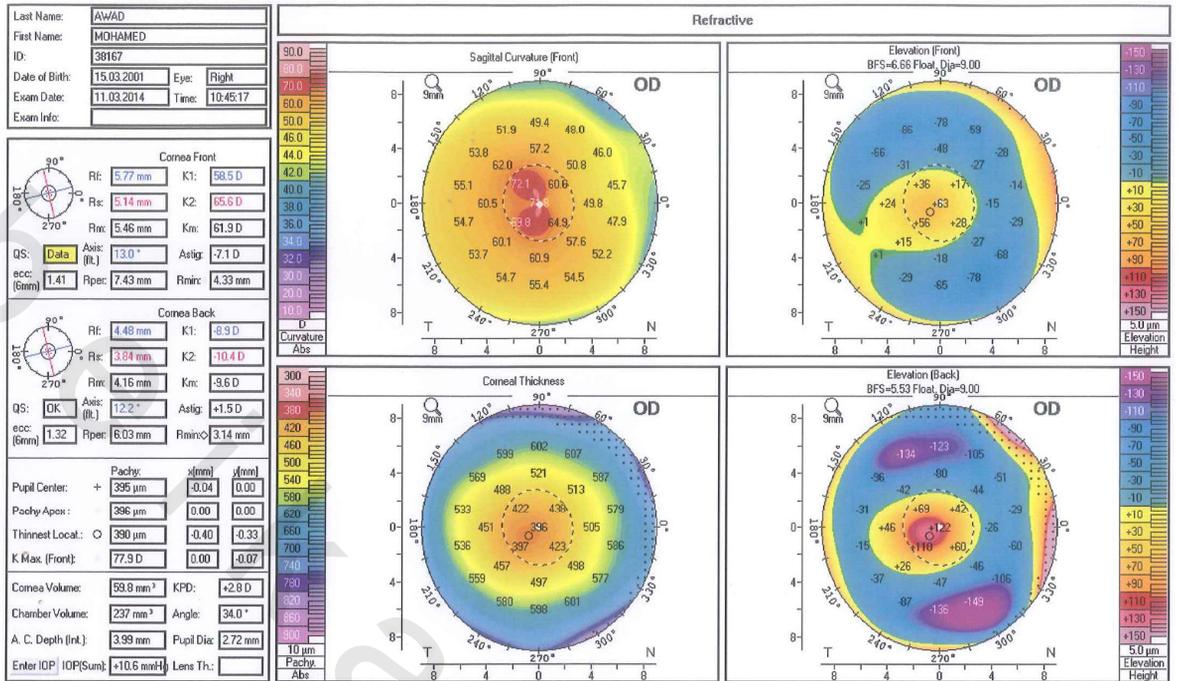


Figure 37: Preoperative pentacam of one eye of group IIB cases

WAVELIGHT - ALLEGRO OCULYZER

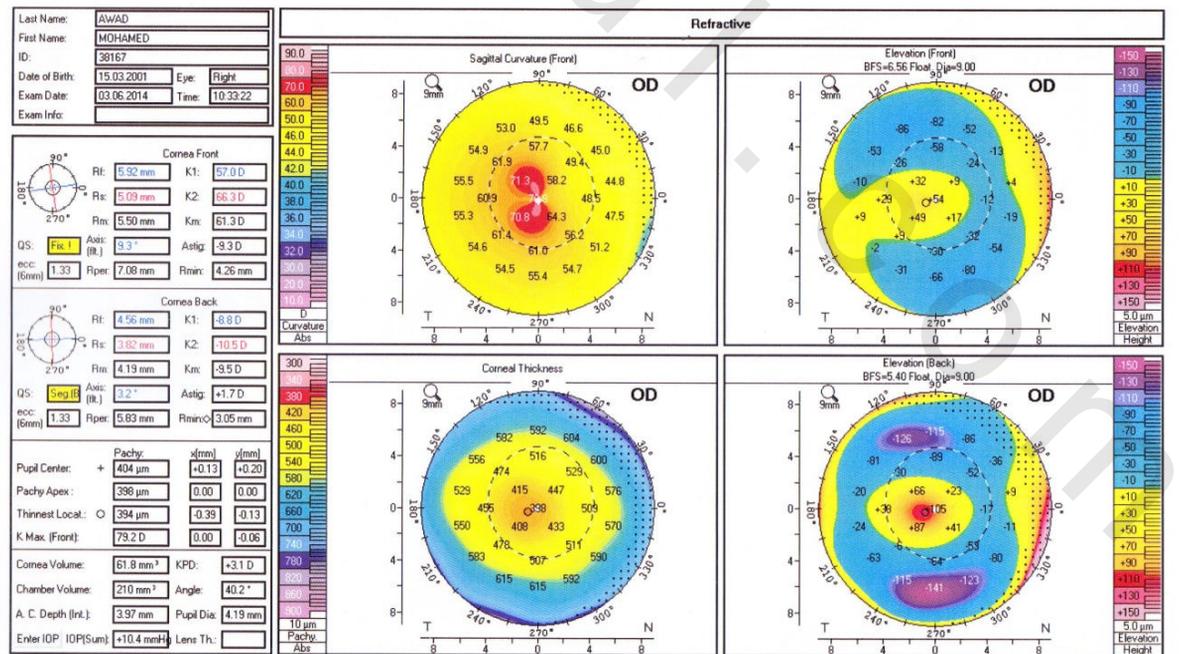


Figure 38: Postoperative pentacam of one eye of group IIB cases