

RESULTS

The study was carried out on 60 eyes diagnosed as a progressive keratoconus, divided into 2 groups as follow; patients were treated with collagen cross-linking alone (**group I**), and patients underwent collagen cross-linking combined with simultaneous femtosecond laser-assisted intra-stromal corneal ring segment (**group II**). The data was collected, tabulated, and analyzed as follow:

Demographic data:

Number:

The total number of participant is 60 eyes, divided between both groups; GroupI recruited 30 eyes of 20 patients and Group II recruited 30 eyes of 24 patients.

Age:

- **Group I:** The mean age of the studied cases was 26.33 ± 6.00 years with a range 19-35 year.
- **Group II:** The mean age of the studied cases was 26.93 ± 5.85 years with a range 18-36 year.

Gender:

- Most of the cases (26) in **Group I** were females(86.67%) who significantly exceed the remaining 4 males (13.33%), but in **Group II** there were no significant difference in gender distribution; there were 16 males(53.33%) and 14 females (46.67%).
- **Table I** illustrates age and gender distribution among the studied cases (**Figure 1A, 1B**).

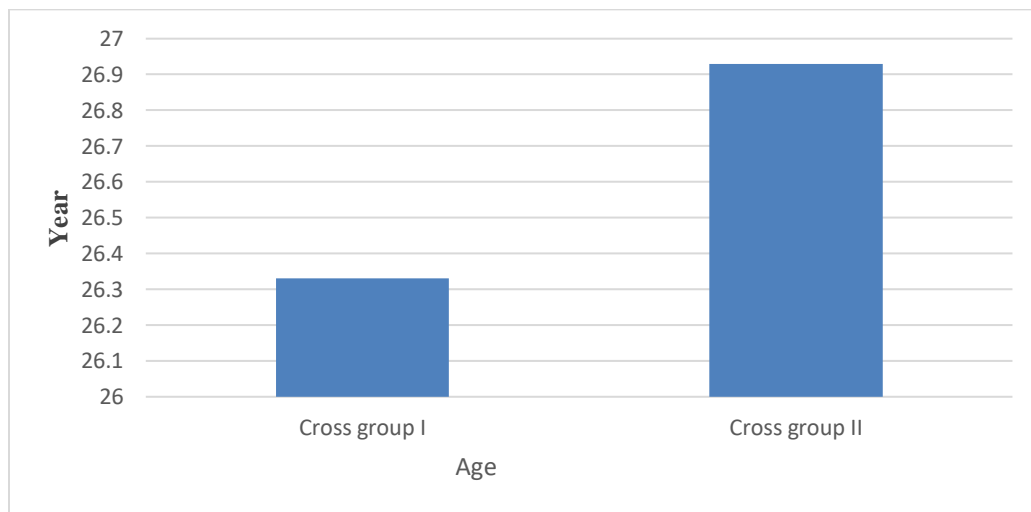
Table (1): Age and gender distribution of the two studied groups

	Group I		Group II		T = 0.103 P = 0.236
<u>Age</u>					
Range	19 – 35		18 – 36		
Mean ± SD	26.33 ± 6.00		26.93 ± 5.85		
<u>Gender</u>	NO	%	NO	%	X2 = 9.2 P = 0.001*
Male	4	13.33	16	53.33	
Female	26	86.67	14	46.67	

X^2 = Chi square test

T= student t-test

*: Statistically significant at $p \leq 0.05$

**Figure (1A):** Age distribution of the two studied groups.

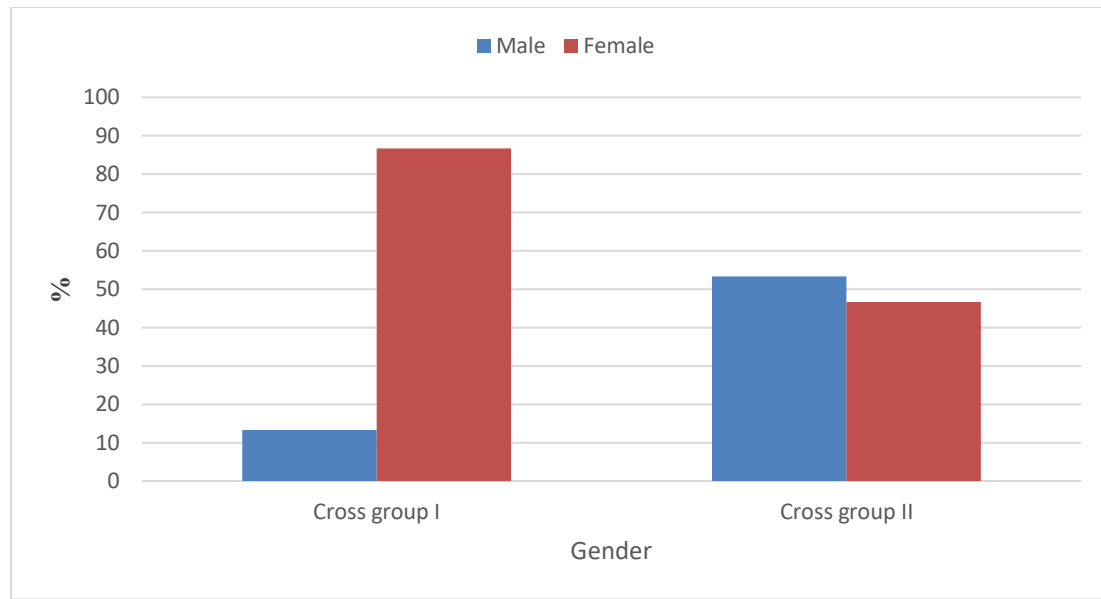


Figure (1B): gender distribution of the two studied groups.

Clinical outcomes:

Visual outcomes:

Unaided visual acuity (UAVA), best corrected visual acuity (BCVA) and pinhole visual acuity (PHVA) outcomes by log MAR unit at the pre-operative and different follow up periods (3, 6, and one year) are shown in tables (2, 3, 4) and figures (2, 3, 4).

Unaided visual acuity (UAVA):

- There were continuous improvement in the unaided visual acuity in both groups throughout the follow up visits as shown in the table (2) and figure(2).
- The mean pre-operative log MAR visual acuity in **group I** was 0.48 ± 0.35 (SD) and at 3, 6, one year follow up was 0.47 ± 0.27 , 0.32 ± 0.22 , 0.29 ± 0.21 (SD) log MAR respectively. In **group II** the mean and standard deviation was 0.649 ± 0.239 log MAR preoperatively, and 0.514 ± 0.222 , 0.419 ± 0.162 , 0.379 ± 0.142 (SD) log MAR at the 3 follow up periods respectively.
- While this improvement was started to be significant in **Group I** after 6 months and continued to one year follow up ($p = 0.022$, $p = 0.009$ respectively), in **group II** it was significant at all follow up periods ($p = 0.014$ at 3 months and $p = 0.000$ at 6 months and one year).
- By comparison regarding the percent change from the pre-operative values, **group II** changed by 20.76% at 3 months follow up compared to 1.4% in **group I** which was

significant ($P=0.0028$), but there were no significant difference in the other follow up periods.

Table (2): Comparison between the two studied groups regarding the **UAVA** at different periods of follow up.

UAVA (Log Mar)	Group I				Group II			
	Pre- Op	3 month	6 month	One year	Pre- Op	3 month	6 month	One year
Mean ± SD	0.48± 0.35	0.47± 0.27	0.32± 0.22	0.29± 0.21	0.649± 0.239	0.514± 0.222	0.419± 0.162	0.379± 0.142
Range	0.10- 1.30	0.18- 1.30	0.10- 0.78	0.10- 0.78	0.3-1.3	0.18-1.3	0.1-0.78	0.1-0.6
P1		0.467	0.022*	0.009*		0.014*	0.000*	0.000*
Mean difference		-0.01	-0.16	-0.18		-0.13	-0.23	-0.27
Mean % Change		-1.40	-32.63	-38.10		-20.76	-35.35	-41.62
P2	Pre Op		3 months		6 month		One year	
			0.0028*		0.63		0.41	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

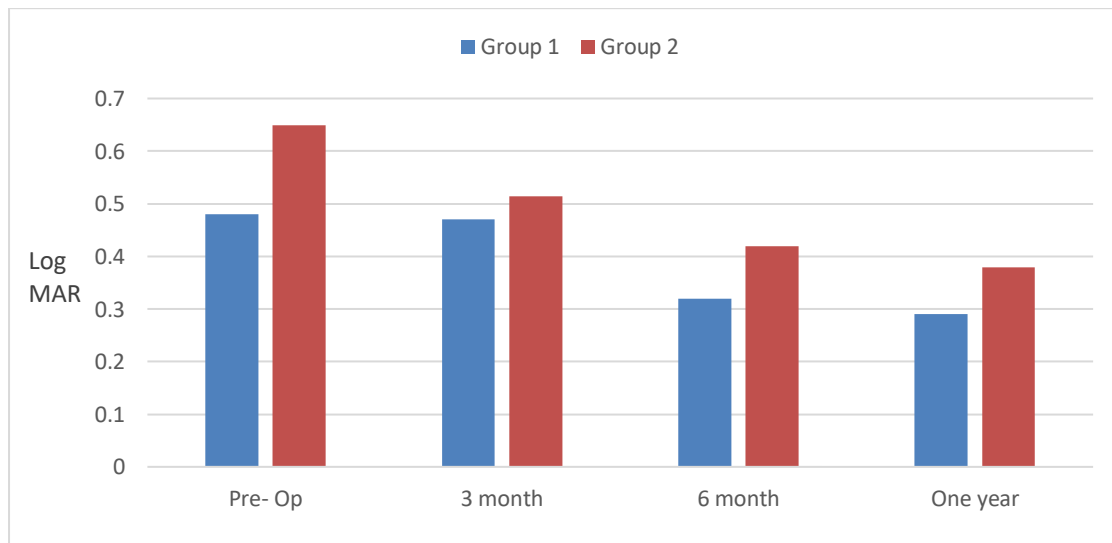


Fig. (2): Comparison between the two studied groups regarding the **UAVA** at different periods of follow up.

Best corrected visual acuity (BCVA): (Table 3)

- Both groups showed insignificant decrease in the best corrected visual acuity at the first 3 months, and then it continued to improve at 6 months towards one year of follow up as shown in the table (3) and figure (3).
- The mean pre-operative log MAR best corrected visual acuity in **group I** was 0.22 ± 0.24 (SD) and at 3, 6, one year follow up was 0.24 ± 0.17 , 0.18 ± 0.18 , 0.15 ± 0.18 (SD) log MAR respectively. In group II the mean and standard deviation was 0.326 ± 0.144 log MAR preoperatively and 0.348 ± 0.151 , 0.279 ± 0.124 , 0.231 ± 0.140 (SD) log MAR at the 3 follow up periods respectively.
- The improvement in BCVA was significant only in **Group II** after one year follow up ($p = 0.006$) and it was also a significant difference in comparison to **group I** ($p = 0.011$).

Table (3): Comparison between the two studied groups regarding the **BAVA** at different periods of follow up.

BCVA (Log Mar)	Group I				Group II			
	Pre-Op	3 month	6 month	One year	Pre- Op	3 month	6 month	One year
Mean ± SD	0.22 ± 0.24	0.24 ± 0.17	0.18 ± 0.18	0.15 ± 0.18	0.326 ± 0.144	0.348 ± 0.151	0.279 ± 0.124	0.231 ± 0.140
Range	0.00-0.78	0.00-0.60	0.00-0.60	0.00-0.60	0.1-0.6	0-0.6	0 - 0.48	0 - 0.48
P1		0.366	0.225	0.078		0.283	0.088	0.006*
Mean difference		0.02	-0.04	-0.08		0.02	-0.05	-0.10
Mean % Change		8.31	-18.40	-35.46		6.75	-14.52	-29.24
P2	Pre Op		3 months		6 month		One year	
			0.14		0.27		0.011*	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

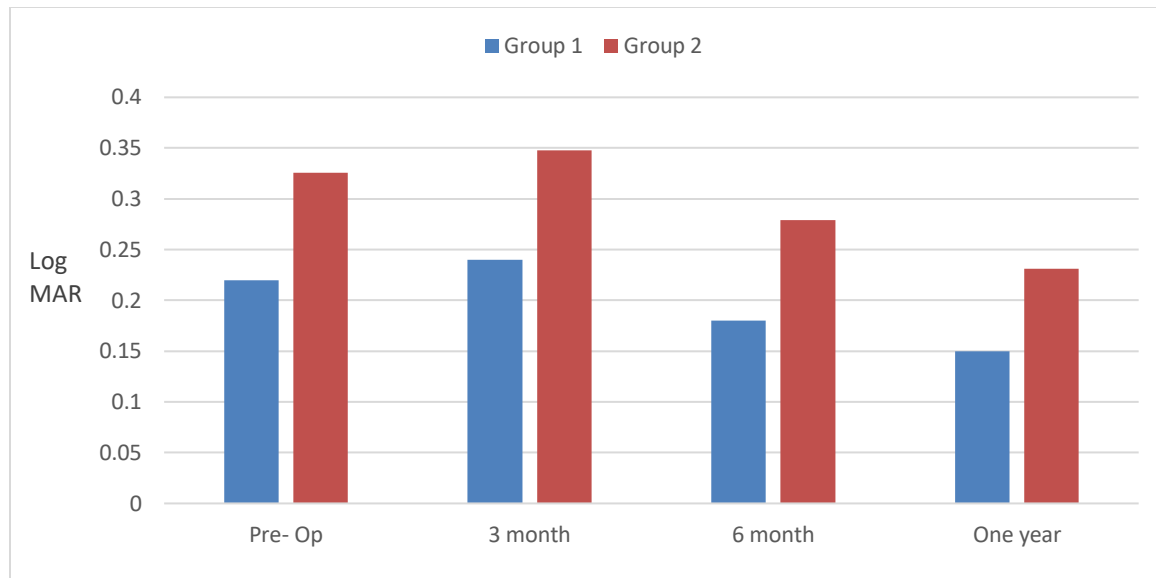


Fig.(3): Comparison between the two studied groups regarding BCVA at different period of follow up.

Pinhole visual acuity (PHVA):

- There were continuous improvement in the pinhole visual acuity in both groups as shown in the table (4) and figure (4) throughout the follow up visits
- The mean pre-operative log MAR pinhole visual acuity in group I was 0.21 ± 0.29 (SD) and at 3, 6, one year follow up was 0.21 ± 0.17 , 0.17 ± 0.18 , 0.15 ± 0.18 (SD) log MAR respectively. In group II the mean and standard deviation was 0.299 ± 0.139 log MAR preoperatively, and 0.291 ± 0.143 , 0.250 ± 0.141 , 0.228 ± 0.136 (SD) log MAR at the 3 follow up periods respectively.
- The improvement in the PHVA was significant only in **Group II** after one year follow up ($p= 0.025$) and the difference in the percent change between both groups was significant only after 3 months of follow up ($p = 0.046$), then there were insignificant difference between groups in the next follow ups.

Table (4): Comparison between the two studied groups regarding the **PHVA** at different periods of follow up.

PHVA (Log Mar)	Group I				Group II			
	Pre-Op	3 month	6 month	One year	Pre- Op	3 month	6 month	One year
Mean ± SD	0.21 ± 0.29	0.21 ± 0.17	0.17 ± 0.18	0.15 ± 0.18	0.299 ± 0.139	0.291 ± 0.143	0.250 ± 0.141	0.228 ± 0.136
Range	0.00-1.40	0.00-0.60	0.00-0.60	0.00-0.60	0.1- 0.6	0-0.6	0 - 0.48	0 - 0.48

P1		0.496	0.238	0.160		0.410	0.094	0.025*
Mean difference		0.00	- 0.04	- 0.06		- 0.01	- 0.05	- 0.07
Mean % Change		0.31	-20.75	-29.25		-2.79	-16.27	- 23.75
P2	Pre Op	3 months		6 month		One year		
		0.046*		0.103		0.253		

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

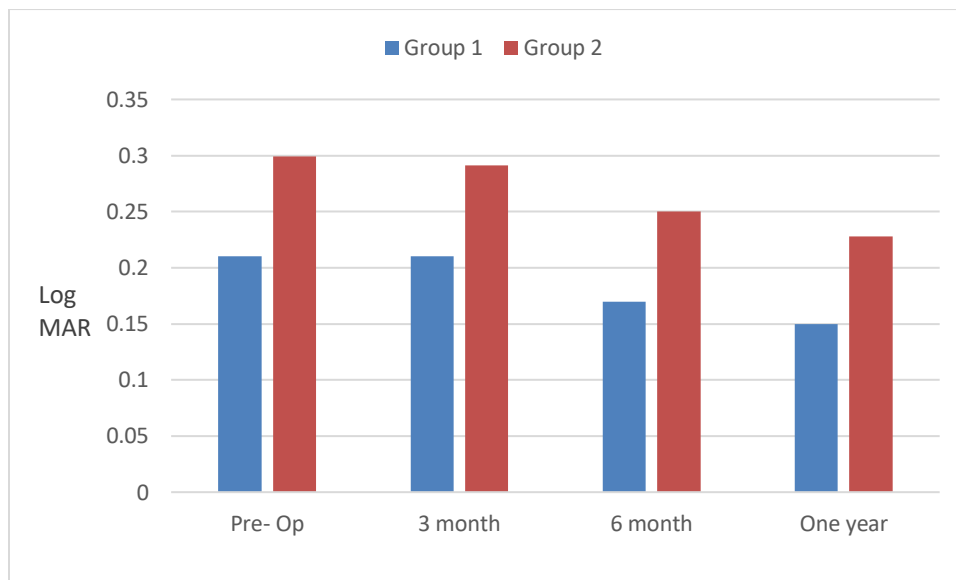


Fig.(4): Comparison between the two studied groups regarding PHVA at different period of follow up.

Refractive outcomes (D):

The spherical equivalent refraction (SE) and refractive astigmatism at the pre-operative and different periods of follow up; 3, 6 and 12 months in each group and comparison between groups are shown in tables (5, 6) and figures (5, 6).

- In each group there were a decrease in the mean dioptic SE refraction through the all follow up periods as shown in table (5) and figure (5).

- The mean pre-operative spherical equivalent refraction in group I was -3.29 ± 2.68 D and at 3, 6, one year follow up was -2.80 ± 2.37 , -2.05 ± 2.32 , -1.96 ± 2.24 D respectively. In group II the mean and standard deviation was -3.45 ± 2.31 D preoperatively and -2.69 ± 1.85 , -2.42 ± 1.73 , -2.11 ± 1.84 D at the 3 follow up periods respectively.
- In each group this improvement was insignificant early after 3 months but it becomes significance after 6 months ($p= 0.0314$ for group I, and $p= 0.0298$ for group II) till after one year ($p= 0.0269$ for group I, and $p= 0.0081$ for group II) follow up.
- The differences between both groups were insignificant at the 3 follow up periods.

Table (5): Comparison between the two studied groups regarding the spherical equivalent refraction (SE) at different periods of follow up.

SE (D)	Group I				Group II			
	Pre-Op	3 month	6 month	One year	Pre- Op	3 month	6 month	One year
Mean \pm SD	-3.29 \pm 2.68	-2.80 \pm 2.37	-2.05 \pm 2.32	-1.96 \pm 2.24	-3.45 \pm 2.31	-2.69 \pm 1.85	-2.42 \pm 1.73	-2.11 \pm 1.84
Range	- 8.5 to 1.5	- 6.5 to 1.75	-7 to 1.5	- 6 to 1.5	- 8.0 to 0.5	- 6.5 to 0.75	- 6.5 to 0.5	- 6 to 2
P1		0.232	0.0314*	0.0269*		0.194	0.0298*	0.0081*
Mean difference		0.49	1.24	1.33		0.76	1.03	1.34
Mean % Change		14.9	37.7	40.4		22.0	29.9	38.8
P2	Pre Op		3 months		6 month		One year	
			0.068		0.062		0.1221	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

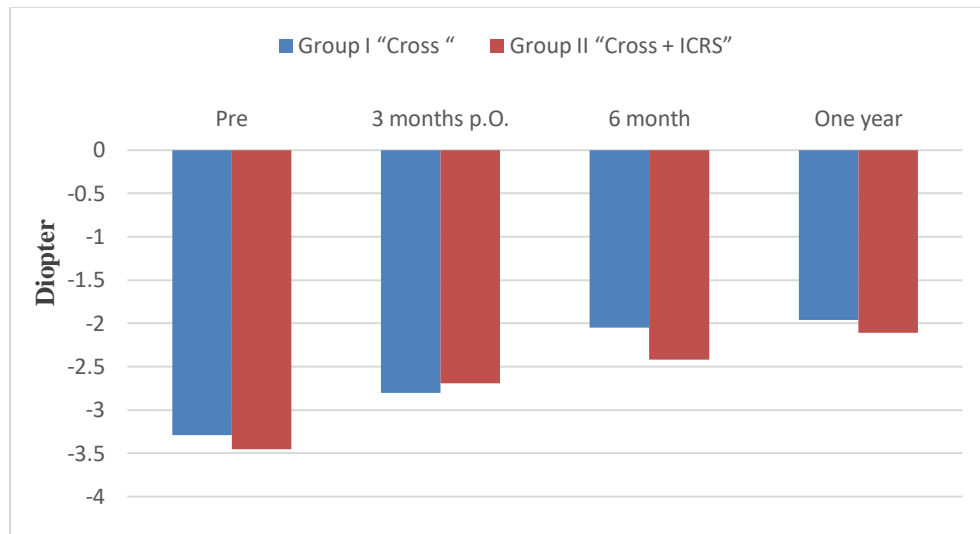


Fig.(5): Comparison between the two studied groups regarding spherical equivalent refraction (SE) at different period of follow up.

- Although in **group I** there were no much dioptric changes in the refractive astigmatism through the follow up periods, there were improvements from the pre-operative values though insignificant. But in **group II** there were significant decrease in the mean values at 3 months ($p= 0.002$), 6 months and one year follow up ($p= 0.000$) from the mean pre-operative values.
- The mean pre-operative refractive astigmatism in **group I** was $2.8\pm1.4D$ and at 3, 6, one year follow up was 2.4 ± 1.3 , 2.4 ± 1.1 , $2.4\pm1.1D$ respectively. In **group II** the mean and standard deviation was $4.7\pm1.6 D$ preoperatively and 3.5 ± 1.3 , 2.9 ± 1.2 , $2.6\pm1.1 D$ at the 3 follow up periods respectively.
- Group II** was significantly different from **group I** regarding the percent change comparison at 3 months ($p= 0.017$), at 6 months ($p= 0.02$), and at one year follow up period ($p= 0.015$) as shown in table (6) and figure (6).

Table (6): Comparison between the two studied groups regarding **refractive astigmatism** at different periods of follow up.

Refractive astigmatism (D)	Group I				Group II			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	2.8 ± 1.4	2.4 ± 1.3	2.4 ± 1.1	2.4 ± 1.1	4.7 ± 1.6	3.5 ± 1.3	2.9 ± 1.2	2.6 ± 1.1
Range	0.3 -	0.3 -	1.0 -	1.0 -	1.3 -	1.5 -	1.0 -	0.8 -

	5.5	5.0	4.5	4.5	8.0	7.5	7.5	6.0
P1		0.131	0.103	0.113		0.002*	0.000*	0.000*
Mean difference		-0.41	-0.43	-0.42		-1.16	-1.76	-2.03
Mean % Change		-14.58	-15.50	-15.01		-24.75	-37.74	-43.39
P2	Pre Op	3 months		6 month		One year		
		0.017*		0.02*		0.015*		

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

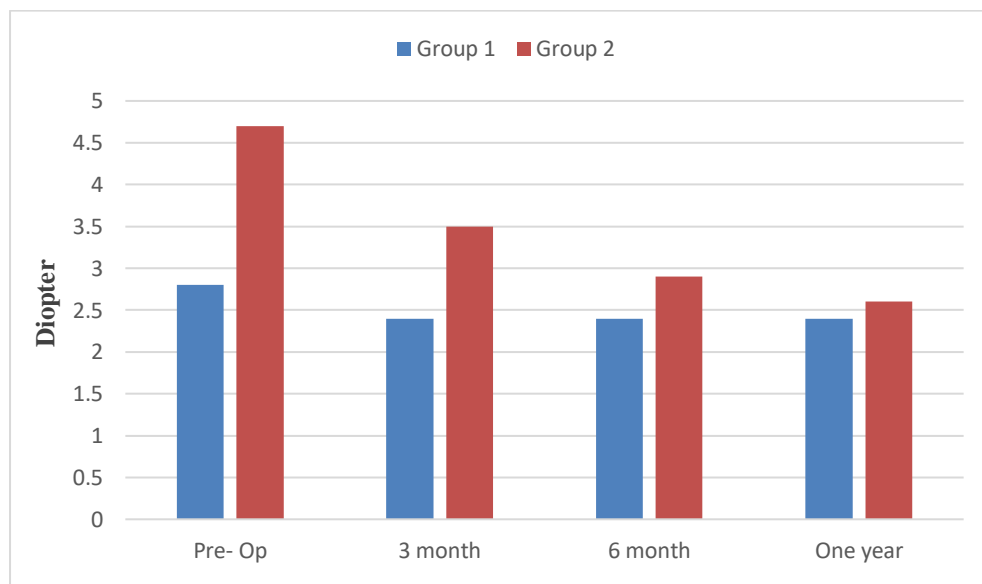


Fig.(6): Comparison between the two studied groups regarding **refractive astigmatism** at different period of follow up.

Topographic outcomes:

Keratometric values:

The mean flattest k (**k1**), the steepest k (**K2**), and the maximum k (**k_{Max}**) illustration in tables (8, 9, 10) and figures (8, 9, 10), and the percent change comparison between groups shown as follow:

- The mean pre-operative flattest k (k1) in **group I** was $44.71 \pm 3.14D$ and at 3, 6, one year

follow up was 44.77 ± 3.44 , 44.44 ± 3.28 , 44.24 ± 3.20 D respectively. In **group II** the mean and standard deviation was 47.30 ± 3.60 D preoperatively and 46.43 ± 3.27 , 46.18 ± 2.95 , 45.85 ± 3.46 D at the 3 follow up periods respectively (table 8) (figure 8).

- Despite decreased flattening in **group I** at 3 months, there were continues flattening effect after 6 months till after one year follow up, but all these changes were insignificant. In **group II** the flattening effect started from after 3 months throughout one year follow up period, and also was insignificant. Although the combined procedure resulted in more flattening effect than cross linking alone, the differences were insignificant.

Table (8): Comparison between the two studied groups regarding the flattest k (**K1**) at different periods of follow up.

Flattest k (D)	Group I				Group II			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	44.71 ± 3.14	44.77 ± 3.44	44.44 ± 3.28	44.24 ± 3.20	47.30 ± 3.60	46.43 ± 3.27	46.18 ± 2.95	45.85 ± 3.46
Range	40 - 54.7	39.3 - 54.9	39 - 53.4	39 - 53.2	40.5 - 55.2	40.3 - 53.8	40.9 - 52.5	38.7 - 55.8
P1		0.475	0.371	0.283		0.168	0.097	0.061
Mean difference		0.06	- 0.27	- 0.47		- 0.87	-1.12	-1.45
Mean % Change		-0.1	0.6	1.1		1.8	2.4	3.1
P2	Pre Op		3 months		6 month		One year	
			0.123		0.652		0.254	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

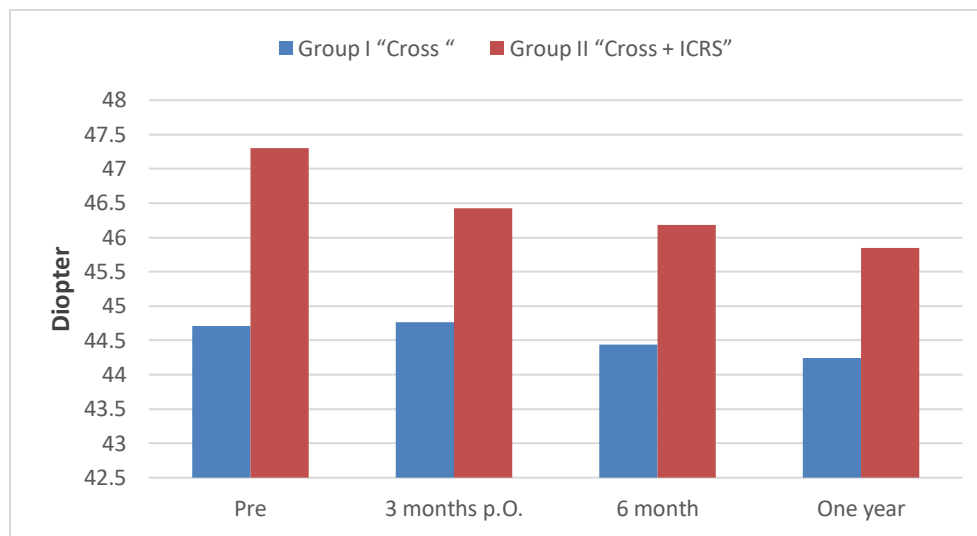


Fig.(8): Comparison between the two studied groups regarding the flattest k (**K1**) at different period of follow up.

- The mean pre-operative steepest k (**K2**) in **group I** was $47.97 \pm 3.62D$ and at 3, 6, one year follow up was 48.01 ± 3.66 , 47.66 ± 3.61 , $47.39 \pm 3.59D$ respectively. In **group II** the mean and standard deviation was $51.89 \pm 3.81D$ preoperatively and 50.32 ± 4.49 , 49.87 ± 4.57 , $49.40 \pm 4.39D$ at the 3 follow up periods respectively (table 9), (figure 9).
- There were early insignificant increase in the steepest k in **group I** at 3 months followed by continues decrease in steepening after 6 months till after one year follow up and was also insignificant. **Group II** resulted in decreased steepening that was significant after 6 months ($p= 0.034$) and after one year ($p= 0.011$) follow up. Although the combined procedure resulted in more decrease in steepest k than cross linking alone, the differences were insignificant.

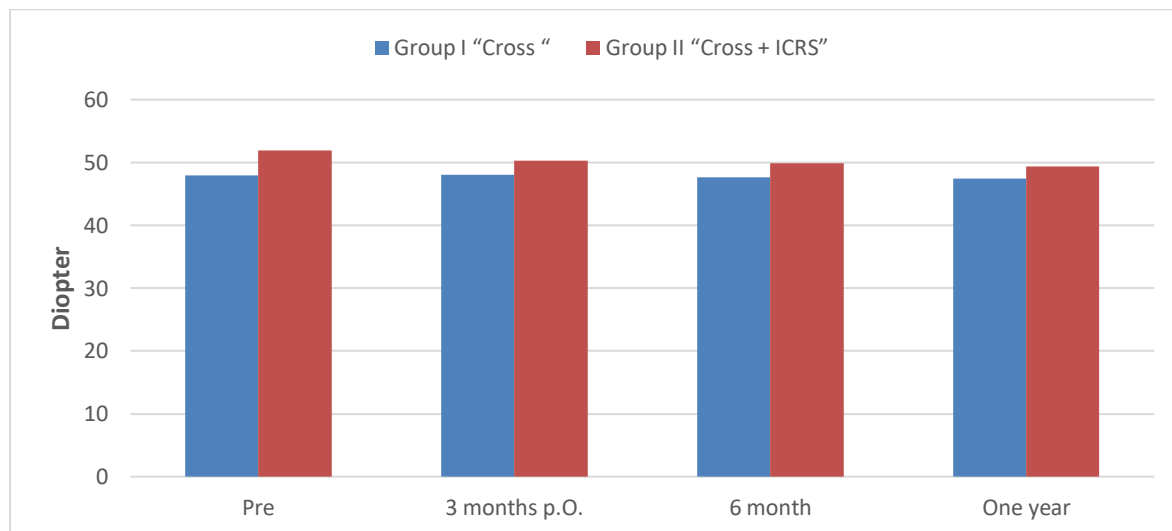
Table (9): Comparison between the two studied groups regarding the steepest k (**K2**) at different period of follow up.

steepest k (D)	Group I				Group II			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	47.97 \pm 3.62	48.01 \pm 3.66	47.66 \pm 3.61	47.39 \pm 3.59	51.89 \pm 3.81	50.32 \pm 4.49	49.87 \pm 4.57	49.40 \pm 4.39
Range	43.3-60.5	43.1-59.8	41.9-58.7	41.7-58.7	45.2-59.5	42.1-59	41.8-60.2	42.3-60.9
P1		0.482	0.371	0.269		0.074	0.034*	0.011*
Mean difference		0.04	- 0.31	- 0.58		-1.57	-2.02	-2.49
Mean % Change		-0.1	0.6	1.2		3.0	3.9	4.8
P2	Pre Op	3 months		6 month		One year		
		0.106		0.452		0.785		

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*:Statistically significant at $p \leq 0.05$

**Fig.(9):** Comparison between the two studied groups regarding the steepest k (**K2**) at different period of follow up.

- The mean pre-operative maximum k (K_{MAX}) in **group I** was $52.23 \pm 5.53D$ and at 3, 6, one year follow up was 52.17 ± 5.41 , 51.52 ± 5.49 , $51.22 \pm 5.43D$ respectively. In **group II** the mean and standard deviation was $57.73 \pm 5.92D$ preoperatively and 57.16 ± 6.52 , 56.21 ± 6.49 , $55.83 \pm 5.94D$ at the 3 follow up periods respectively (table 10), (figure 10).
- Both groups showed insignificant decrease in the values of the maximum k from the pre-operative values through all follow up periods. **Group II** resulted in more decrease in maximum k than **group I** but the difference was insignificant.

Table (10): Comparison between the two studied groups regarding the maximum k (K_{MAX}) at different period of follow up.

K_{MAX} (D)	Group 1				Group 2			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	52.23 \pm 5.53	52.17 \pm 5.41	51.52 \pm 5.49	51.22 \pm 5.43	57.73 \pm 5.92	57.16 \pm 6.52	56.21 \pm 6.49	55.83 \pm 5.94
Range	45.2-64.9	44.1-65.4	44 - 64	44 - 64.2	47.1-68.2	46.8 - 69.9	45.1 - 68.6	46 - 67.2
P1		0.481	0.308	0.238		0.362	0.173	0.109
Mean diff		- 0.06	- 0.71	-1.01		- 0.57	-1.52	- 1.9
Mean % Change		0.1	1.4	1.9		1.0	2.6	3.3
P2	Pre Op		3 months		6 month		One year	
			0.23		0.158		0.223	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

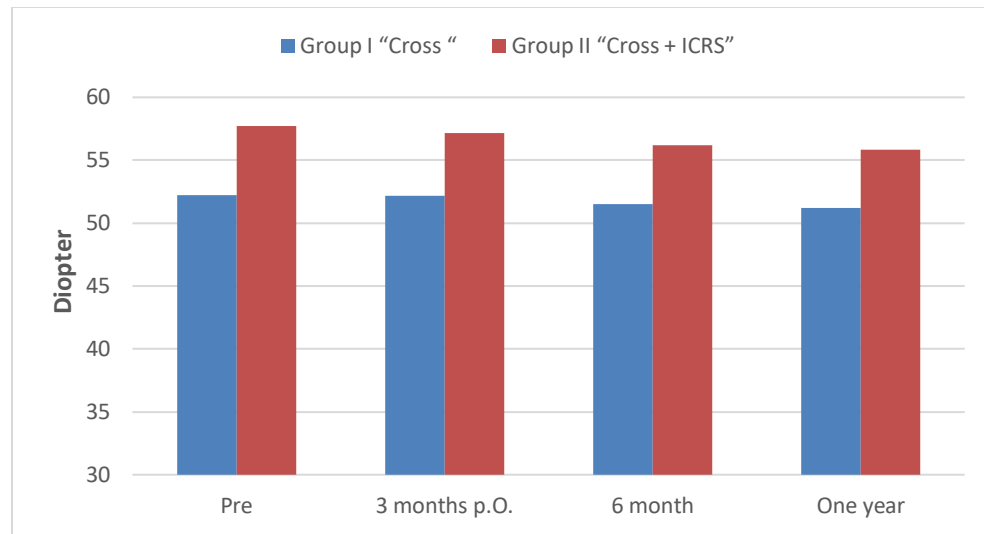


Fig.(10): Comparison between the two studied groups regarding the maximum k (K_{MAX}) at different period of follow up.

keratometric astigmatism:

- The mean pre-operative keratometric astigmatism in **group I** was 3.3 ± 1.7 D and at 3, 6, one year follow up was 3.2 ± 1.7 , 3.1 ± 1.7 , 3.0 ± 1.6 D respectively. In **group II** the mean and standard deviation was 4.6 ± 1.8 D preoperatively and 3.7 ± 1.8 , 3.9 ± 1.9 , 3.5 ± 1.6 D at the 3 follow up periods respectively.
- **Group I** showed no significant changes in the keratometric astigmatism but in **group II** there were significant decrease in the mean values at 3 months ($p = 0.041$), and at one year follow up ($p = 0.010$) from the mean pre-operative values.
- **Group II** was significantly different from **group I** regarding the percent change comparison at 3 months ($p = 0.025$), at 6 months ($p = 0.041$), and at one year follow up period ($p = 0.033$) as shown in table (7) and figure (7).

Table (7): Comparison between the two studied groups regarding **keratometric astigmatism** at different periods of follow up.

keratometric astigmatism (D)	Group I				Group II			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	3.3 \pm 1.7	3.2 \pm 1.7	3.1 \pm 1.7	3.0 \pm 1.6	4.6 \pm 1.8	3.7 \pm 1.8	3.9 \pm 1.9	3.5 \pm 1.6
Range	0.5 - 7.7	0.5 - 7.6	0.4 - 7.5	0.4 - 7.5	0.5 - 7.7	0.1 - 6.3	0.4 - 7.9	0.4 - 6.2
P1		0.459	0.347	0.246		0.041*	0.073	0.010*
Mean difference		-1.42	-5.31	-9.19		-18.00	-15.46	-23.27
Mean % Change		-1.42	-5.31	-9.19		-18.00	-15.46	-23.27
P2	Pre Op		3 months		6 month		One year	
			0.025*		0.041*		0.033*	

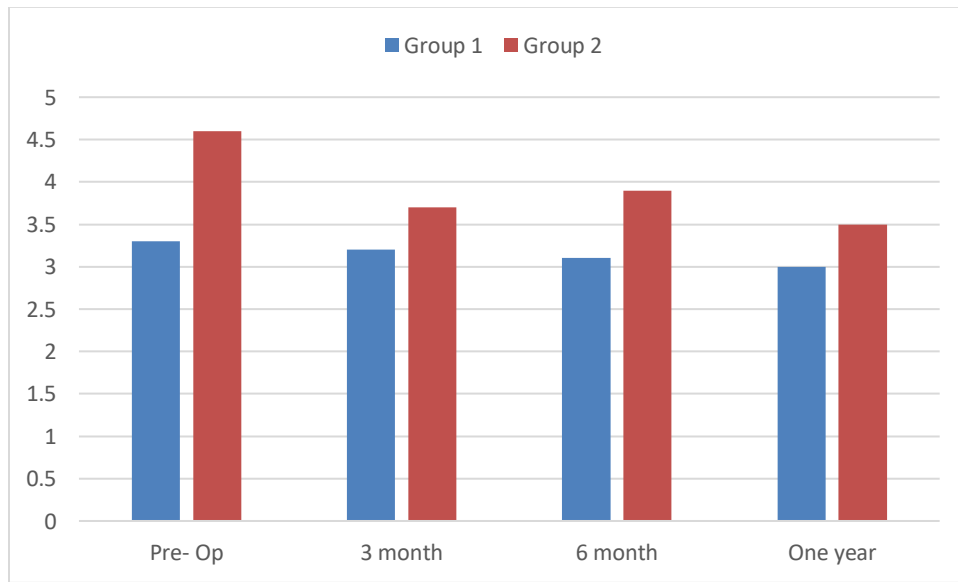


Fig. (7): Comparison between the two studied groups regarding **keratometric astigmatism** at different periods of follow up.

Pachymetric values:

- The mean pre-operative central corneal thickness (CCT) in **group I** was 460.77 ± 50.88 μm and at 3, 6, one year follow up was 445.13 ± 51.03 , 450.97 ± 46.00 , 455.50 ± 47.36 μm respectively. In **group II** the mean and standard deviation was 434.90 ± 40.50 μm preoperatively and at the 3 follow up periods 411.77 ± 43.26 , 419.67 ± 41.73 , 424.67 ± 44.23 μm respectively (table 11), (figure 11).
- Both procedures resulted in corneal thinning compared to the pre-operative central corneal thickness; the most thinning was early at 3 months follow up and it was significant only in **group II** ($p=0.018$). Both groups show less thinning at 6 months and one year follow up, the comparison of percent change between the 2 groups showed no significant difference.

Table (11): Comparison between the two studied groups regarding the pachymetry values (at the thinnest location) at different period of follow up.

Thickness (μm)	Group 1				Group 2			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	460.77 \pm 50.88	445.13 \pm 51.03	450.97 \pm 46.00	455.50 \pm 47.36	434.90 \pm 40.50	411.77 \pm 43.26	419.67 \pm 41.73	424.67 \pm 44.23
Range	362-563	349-559	355-543	360-559	362-520	351-488	345-512	339-512
P1		0.120	0.219	0.340		0.018*	0.078	0.177
Mean diff		-15.64	-9.8	-5.27		-23.13	-15.23	-10.23
Mean % Change		3.4	2.1	1.1		5.3	3.5	2.4
P2	Pre Op		3 months		6 month		One year	
			0.211		0.307		0.58	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

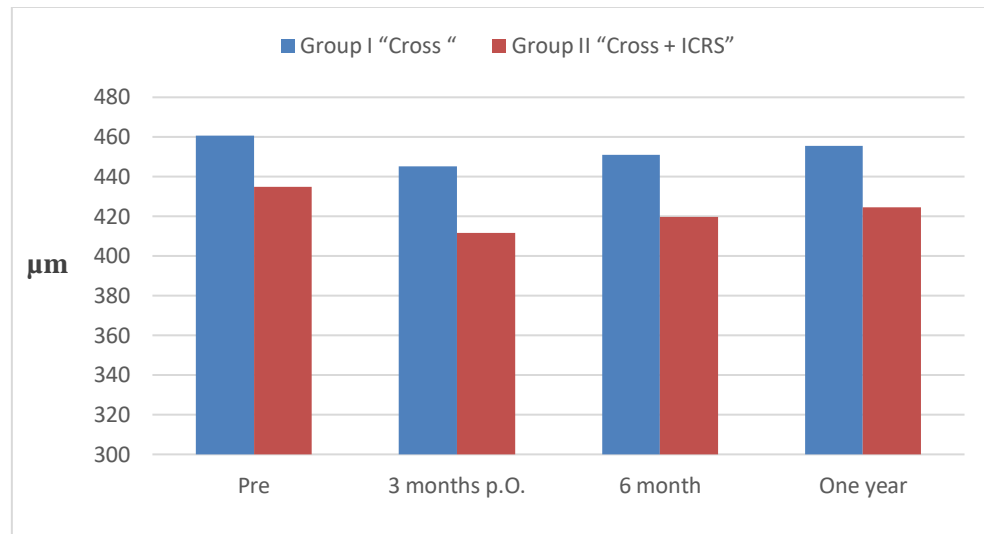


Fig.(11): Comparison between the two studied groups regarding the pachymetry values (at the thinnest location) at different period of follow up.

Corneal Asphericity (Q-value):

- The corneal asphericity (indicated by Q-value) showed no much change throughout the follow up periods in both groups with non significant trends toward improvement (table 11).
- The mean pre-operative Q-value in **group I** was -0.33 ± 0.73 and at 3, 6, one year follow up was -0.40 ± 0.77 , -0.49 ± 0.57 , -0.48 ± 0.54 respectively. In **group II** the mean and standard deviation was -0.48 ± 1.15 preoperatively and at the 3 follow up periods -0.46 ± 1.14 , -0.57 ± 0.94 , -0.80 ± 0.92 respectively (table 12), (figure 12).
- The combined group tends to change the cornea towards the oblate shape early after surgery then the corneal asphericity improved at the next follow ups, these changes were significant when compared to group I at 3 ($p=0.013$) and 6 months ($p=0.0221$) follow up but after one year there were no significant difference.

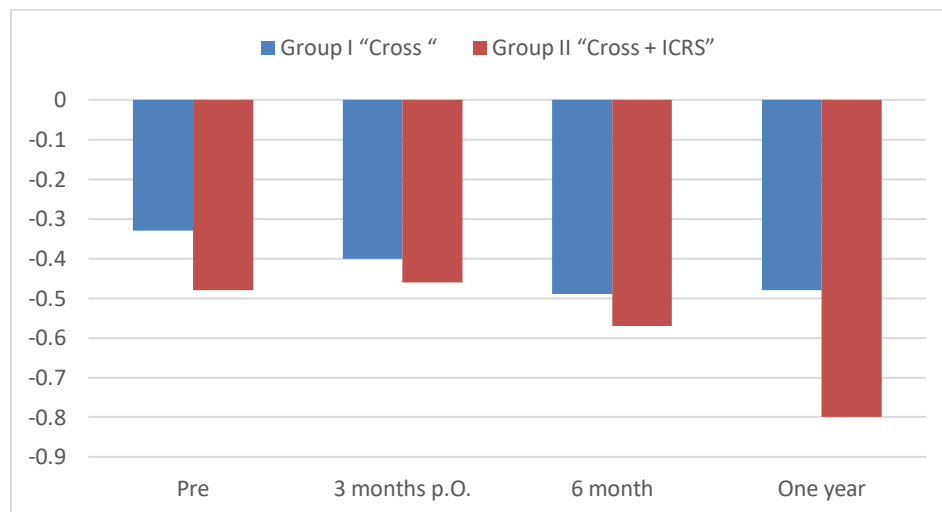
Table (12): Comparison between the two studied groups regarding corneal asphericity (Q value) at different period of follow up.

Corneal asphericity (Q value)	Group 1				Group 2			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	-0.33 \pm 0.73	-0.40 \pm 0.77	-0.49 \pm 0.57	-0.48 \pm 0.54	-0.48 \pm 1.15	-0.46 \pm 1.14	-0.57 \pm 0.94	-0.80 \pm 0.92
Range	-1.75 to 1.14	-1.79 to 1.67	-1.73 to 0.65	-1.73 to 0.61	-2.77 to 1.54	-2.5 to 1.49	-2 to 1.29	-3 to 1.34
P1		0.362	0.174	0.181		0.474	0.367	0.112
Mean diff		-0.07	-0.16	-0.15		0.02	-0.09	-0.32
Mean % Change		-21.2	-48.5	-45.5		4.2	-18.8	-66.7
P2	Pre Op		3 months		6 month		One year	
			0.013*		0.0221*		0.098	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

**Fig.(12):** Comparison between the two studied groups regarding corneal asphericity (Q value) at different period of follow up.

COMA – High Order Aberration by Pentacam:

Table (13) and figure (13) showed the values for The COMA - HOA pre-operatively and at different periods of follow up in both groups:

- The mean pre-operative COMA - HOA in **group I** was 2.21 ± 1.88 and at 3, 6, one year follow up was 2.24 ± 1.80 , 2.06 ± 1.86 , 1.94 ± 1.84 respectively. In **group II** the mean and standard deviation was 3.54 ± 2.10 preoperatively and at the 3 follow up periods - 3.32 ± 1.69 , 2.90 ± 1.57 , 2.87 ± 1.57 respectively (table 12), (figure 12).
- There were insignificant trends toward improvement in both groups and the percent changes comparison of both group also showed no significant difference at all follow up periods.

Table (13): Comparison between the two studied groups regarding COMA – HOA (e -3) at different period of follow up.

COMA-HOA	Group 1				Group 2			
	Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Mean \pm SD	2.21 ± 1.88	2.24 ± 1.80	2.06 ± 1.86	1.94 ± 1.84	3.54 ± 2.10	3.32 ± 1.69	2.90 ± 1.57	2.87 ± 1.57
Range	0.507 - 9.032	0.597 - 8.039	0.513 - 8.367	0.116 - 8.012	0.346 - 7.717	0.713 - 6.711	0.501 - 6.257	0.357 - 6.557
P1		0.479	0.372	0.289		0.330	0.093	0.083
Mean diff		0.03	- 0.15	- 0.27		- 0.22	- 0.64	- 0.67
Mean % Change		-1.4	6.8	12.2		6.2	18.1	18.9
P2	Pre Op		3 months		6 month		One year	
			0.077		0.062		0.271	

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

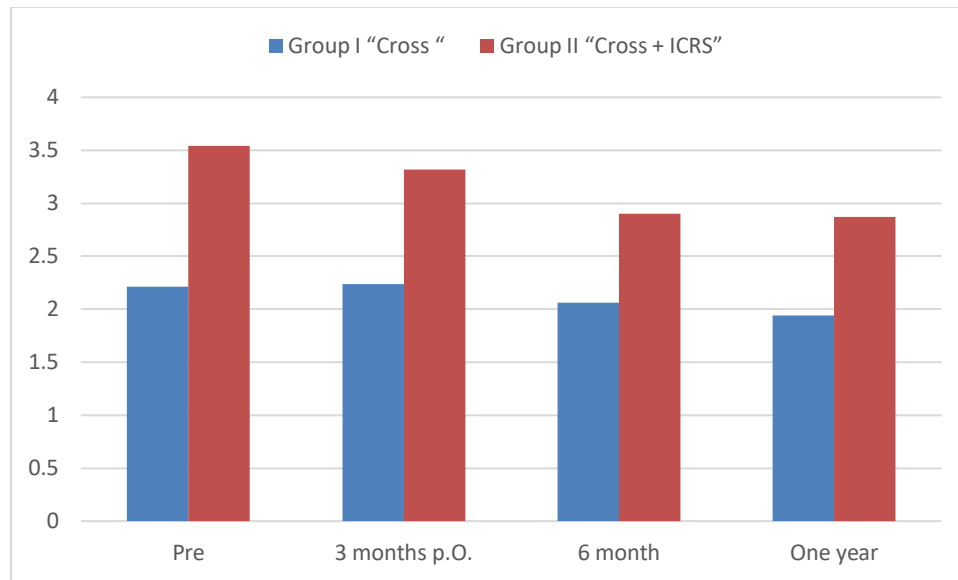


Fig.(13):Comparison between the two studied groups regarding COMA – HOA(e-3) at different period of follow up.

Contrast sensitivity (CS) measurements:

CS was calculated in 3, 6, 12 and 18 c/d frequencies for both groups and was transformed to logarithmic values as shown in tables 14, 15.

Low frequencies CS (Row A& B):

The values of low frequencies contrast sensitivity test of both groups are shown in (table 14) and (figure 14):

- In both groups there was an improvement in the mean log units CS of low frequencies over one year of follow-up from the pre-operative values; in 3c/d frequency, it was not statistically significant, but in 6 c/d it was significant in group I at one year follow up ($p=0.045$) and in group II at all follow up periods, 3,6, one year ($p=0.035, 0.009, 0.032$) respectively.
- The lower frequency comparison of both groups showed no significant difference.

Table (14): Comparison between the two studied groups regarding low frequencies CS - 3c/d (**Row A**) and 6c/d (**Row B**) at different period of follow up.

Low Frequencies (log unit)		Row A (3c/d)				Row B (6c/d)			
		Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Group I	Mean \pm SD	1.22 \pm 0.44	1.25 \pm 0.36	1.32 \pm 0.35	1.39 \pm 0.36	1.50 \pm 0.31	1.54 \pm 0.27	1.59 \pm 0.30	1.63 \pm 0.31
	Range	0.4 - 1.93	0.4 - 1.78	0.7 - 1.93	0.7 - 1.93	0.61 - 1.99	0.91 - 1.99	0.91 - 2.14	0.91 - 2.14
	P1		0.401	0.171	0.061		0.270	0.122	0.045*
	Mean diff		0.03	0.1	0.17		0.04	0.09	0.13
	Mean % Change		- 2.5	- 8.2	- 13.9		- 2.7	- 6.0	- 8.7
Group II	Mean \pm SD	1.13 \pm 0.37	1.19 \pm 0.33	1.32 \pm 0.37	1.26 \pm 0.41	1.40 \pm 0.31	1.55 \pm 0.30	1.58 \pm 0.24	1.54 \pm 0.26
	Range	0.4- 1.63	0.4 - 1.63	0.7- 2.08	0.4 - 1.93	0.61- 1.99	0.91- 1.99	0.91- 1.99	0.91- 1.99
	P1		0.253	0.241	0.099		0.035*	0.009*	0.032*
	Mean diff		0.06	0.19	0.13		0.15	0.18	0.14
	Mean % Change		-5.3	-16.8	-11.5		-10.7	-12.9	-10.0
P2			0.285	0.165	0.789		0.103	0.1444	0.465

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

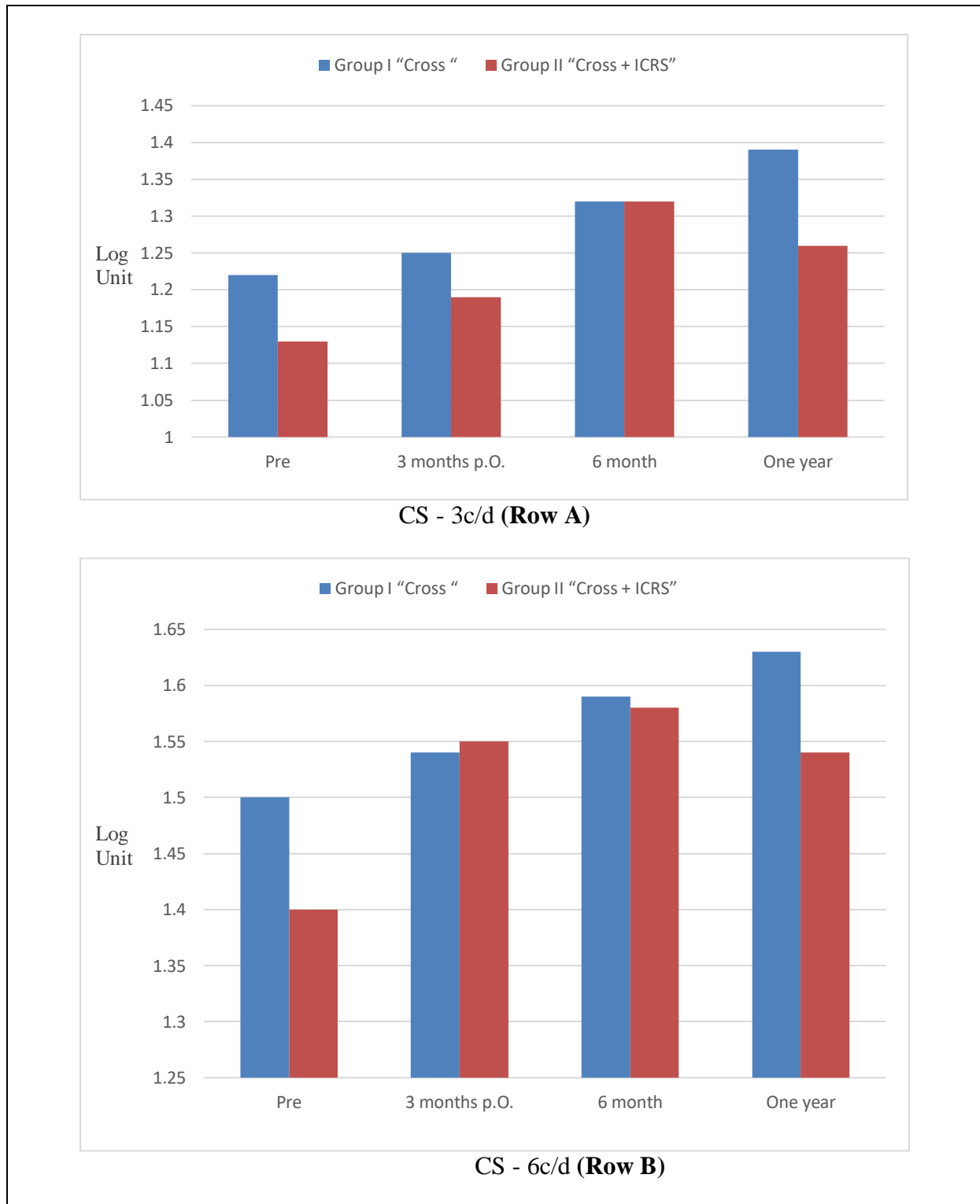


Fig.(14): Comparison between the two studied groups regarding low frequencies CS at different periods of follow up.

High frequencies CS (Row C& D):

The values of high frequencies contrast sensitivity test of both groups are shown in (table 15) and (figure 15):

- In both groups there was an improvement in the mean log units CS of high frequencies over 1year of follow-up from the pre-operative values, and it was statistically significant at 6 months and one year follow up periods.
- For 12 c/d frequency at 6 months and at one year follow up; group I (p= 0.026, 0.003) respectively, and group II (p= 0.036, 0.032) respectively.
- For 18 c/d frequency at 6 months and at one year follow up; group I (p= 0.040, 0.005) respectively, and group II (p= 0.046, 0.018) respectively.
- The higher frequency comparison of both groups showed no significant difference.

Table (15): Comparison between the two studied groups regarding high frequencies CS - 12c/d (Row C) and 18c/d (Row D) at different period of follow up.

High Frequencies (log unit)		Row C (12c/d)				Row D (18c/d)			
		Pre-Op	3 month	6 month	One year	Pre-Op	3 month	6 month	One year
Group I	Mean \pm SD	1.19 \pm 0.24	1.25 \pm 0.25	1.33 \pm 0.32	1.38 \pm 0.28	0.73 \pm 0.33	0.81 \pm 0.28	0.87 \pm 0.31	0.94 \pm 0.28
	Range	0.61-1.99	0.61-1.69	0.61-1.84	0.91-1.99	0.17-1.4	0.17-1.4	0.17-1.4	0.47-1.4
	P1		0.179	0.026*	0.003*		0.162	0.040*	0.005*
	Mean diff		0.06	0.14	0.19		0.08	0.14	0.21
	Mean % Change		- 5.0	-11.8	- 16.0		- 11.0	- 19.2	- 28.8
Group II	Mean \pm SD	1.05 \pm 0.35	1.13 \pm 0.39	1.21 \pm 0.35	1.18 \pm 0.37	0.65 \pm 0.29	0.77 \pm 0.35	0.77 \pm 0.27	0.79 \pm 0.21
	Range	0.31-1.69	0.31-1.99	0.61-1.84	0.31-1.99	-0.13-1.25	0.17-1.4	0.17-1.25	0.47-1.25
	P1		0.202	0.036*	0.032*		0.065	0.046*	0.018*
	Mean diff		0.08	0.16	0.13		0.12	0.12	0.14
	Mean % Change		-7.6	-15.2	-12.4		-18.5	-18.5	-21.5
P2			0.745	0.365	0.411		0.236	0.785	0.582

P1 comparison between mean values pre operatively and different period of follow up

P2 comparison between the two studied groups regarding percent change at different period of follow up.

*: Statistically significant at $p \leq 0.05$

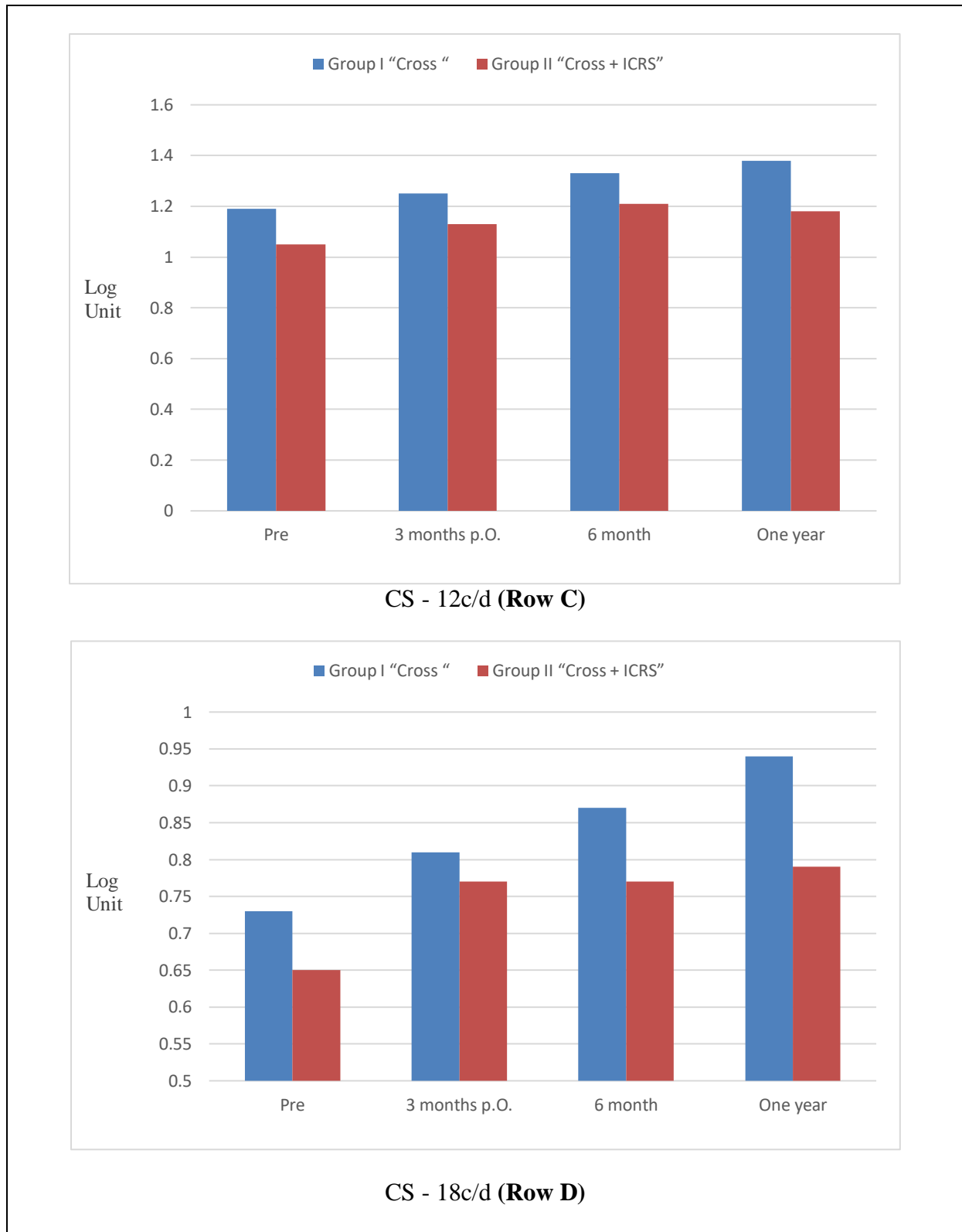


Fig.(15): Comparison between the two studied groups regarding high frequencies CS at different periods of follow up.