

## Results

30 eyes of 18 patients with progressive keratoconus were enrolled in this prospective clinical study. Their ages ranged from 17 to 38 years with a mean age of 25.2 ( $\pm$  6.19 ) years. 9 patients were males(14 eyes) and 9 patients were females(16 eyes).

This study was conducted in ophthalmology department , Benha University Hospital and private centers in the peroid from December 2009 to September 2011.

### • Visual acuity changes after CXL:

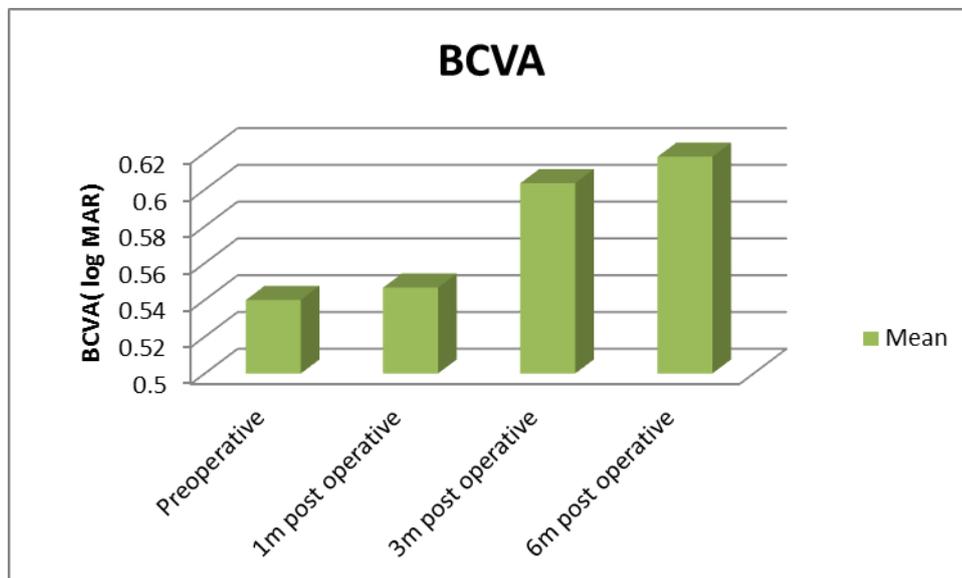
Vision was recorded by snellen's chart & was converted to LogMAR for statistical calculations (table 2).

**Table (2): Best corrected visual acuity (BCVA) before and after CXL treatment.**

BCVA (LogMAR)	Preoperative (n*=30)	Postoperative		
		1 month (n*=30)	3 month (n*=29)	6 month (n*=28)
Mean	0.54	0.55	0.60	0.62
Standard deviation	0.23	0.22	0.21	0.20
Minimum	0.1	0.2	0.2	0.2
Maximum	0.9	0.9	0.9	0.9

N\*=number of cases

The preoperative mean BCVA was  $0.54 (\pm 0.227)$ , with a minimum of (0.1), and a maximum of (0.9). At 1 month postoperative; the mean BCVA improved to  $0.5467 (\pm 0.218)$ , with a minimum of (0.2), and maximum of (0.9). At 3 months postoperative; the mean BCVA further improved to  $0.6034 (\pm 0.209)$ , with a minimum of (0.2), and maximum of (0.9). At 6 months postoperative; the mean BCVA was much improved to  $0.61785 (\pm 0.198)$ , with a minimum of (0.2), and maximum of (0.9) (Fig1).



**Figure 1: The changes in BCVA over time**

The mean BCVA slightly changed at 1 month ( $p = 0.16$ ). The mean BCVA improved significantly at 3 months, and 6 months postoperatively ( $p < 0.05$ ). The BCVA improved by one or more Snellen lines in 63.3% (19 eyes) of eyes & remained stable in 30% (9 eyes) of eyes & 2 eyes (6.66%) lost 1 Snellen line.

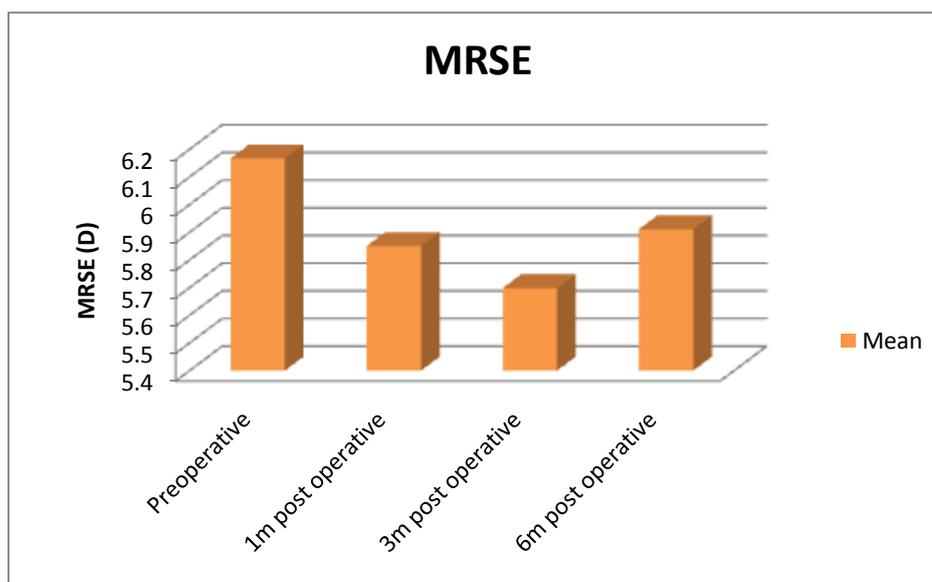
**•Refractive changes after CXL:****A) Manifest refraction spherical equivalent (MRSE):****Table (3): MRSE before and after CXL treatment.**

MRSE (Diopter)	Preoperative (n*=30)	Postoperative		
		1 month (n*=30)	3 month (n*=29)	6 month (n*=28)
<b>Mean</b>	6.17	5.85	5.70	5.91
<b>Standard deviation</b>	3.91	3.83	3.78	3.72
<b>Minimum</b>	-0.5	-0.5	-0.5	-0.5
<b>Maximum</b>	-12.5	-12	-11.5	-11.5

N\*=number of cases

The preoperative mean MRSE was  $-6.167 (\pm 3.909)$ , with a minimum of  $(-0.5)$ , and maximum of  $(-12.5)$ . At 1 month postoperative; the mean MRSE changed to  $-5.85 (\pm 3.826)$ , with a minimum of  $(-0.5)$ , and maximum of  $(-12)$ . At 3 months postoperative ;the mean MRSE further changed to  $-5.698 (\pm 3.782)$  with a minimum and a maximum of  $(-11.5)$ . At 6 months postoperative ;the mean MRSE was  $-5.91 (\pm 3.723)$ , with a minimum of  $(-0.5)$ , and maximum of  $(-11.5)$  (Fig. 2) , (Table 3).

The improvement in the MRSE at 1, 3, and 6 months postoperatively was statistically significant ( $p < 0.05$ ).



**Figure 2: The changes in MRSE over time**

### **b) Refractive astigmatism:**

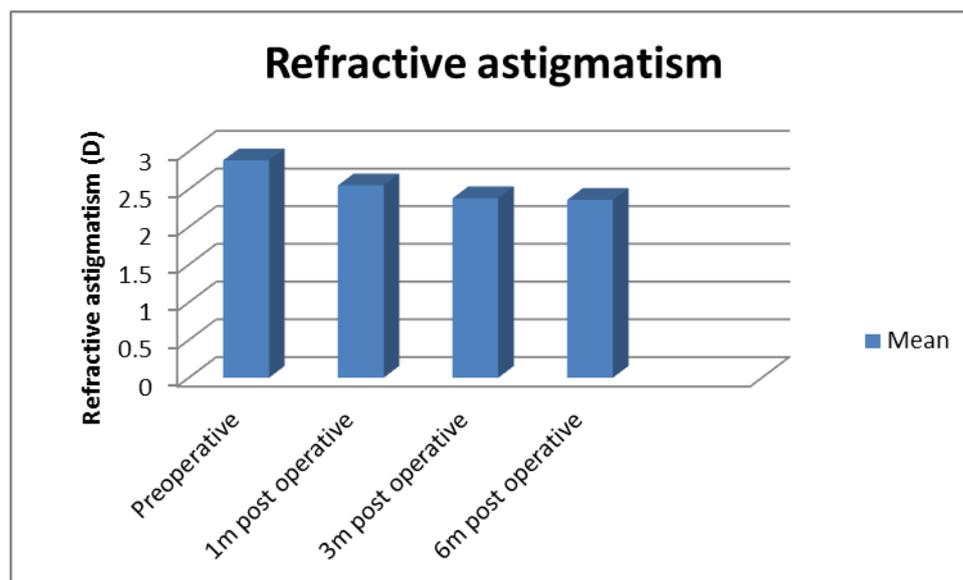
**Table (4): Refractive astigmatism before and after CXL treatment.**

Refractive astigmatism (D <sup>**</sup> )	Preoperative (n <sup>*</sup> =30)	Postoperative		
		1 month (n <sup>*</sup> =30)	3 month (n <sup>*</sup> =29)	6 month (n <sup>*</sup> =28)
<b>Mean</b>	2.88	2.55	2.38	2.36
<b>Standard deviation</b>	1.13	1.18	1.18	1.15
<b>Minimum</b>	0.75	0.5	0.5	0.5
<b>Maximum</b>	4.5	4.5	4	4

N<sup>\*</sup>= Number of cases     D<sup>\*\*</sup>= Diopter

Preoperatively; the mean refractive astigmatism was 2.883( ± 1.133), with a minimum of (0.75),and maximum of (4.5). At 1 month

postoperative; it was 2.55 ( $\pm 1.17$ ), with a minimum of (0.5), and maximum of (4.5). At 3 months postoperative; it was 2.379 ( $\pm 1.177$ ), with a minimum of (0.5) and maximum of (4). At 6 months postoperative; it was 2.357 ( $\pm 1.153$ ), with a minimum of (0.5), and maximum of (4), (Fig. 3) (Table 4)



**Figure 3: The changes in refractive astigmatism over time**

All changes in the mean refractive astigmatism between preoperatively & each postoperative visit was statistically significant ( $p < 0.05$ ).

The refractive astigmatism improved by 1.00 D or more in 4 eyes (13.33%) & changed between -0.5 D & -1D in 66.66% (20/30) eyes & remained stable in 20% (6/30) eyes.

### **•Postoperative topography changes after CXL:**

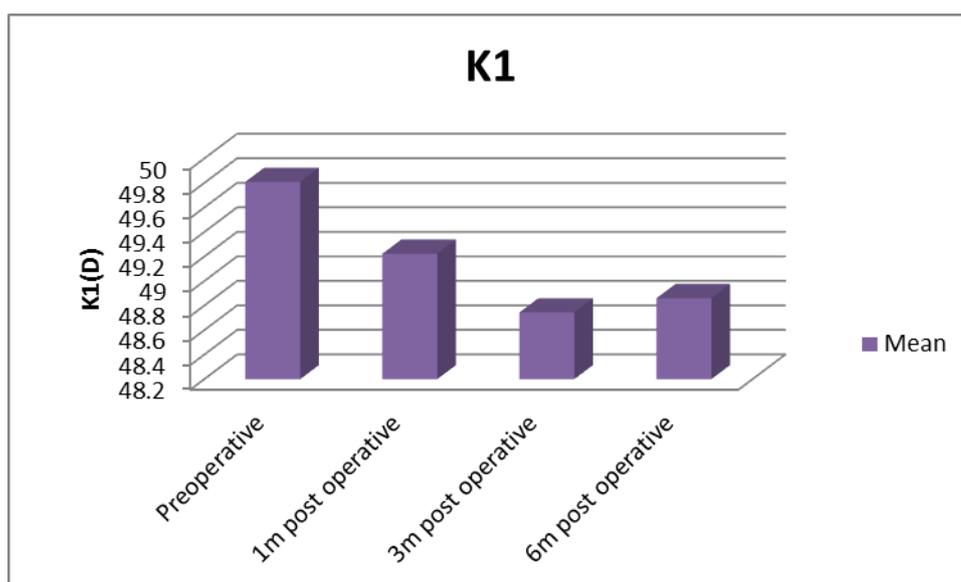
#### **A) Changes in K1 :**

**Table (5): K1 before and after CXL treatment.**

K1(Diopter)	Preoperative (*n=30)	Postoperative		
		1 month (n*=30)	3 month (n*=29)	6 month (n*=28)
<b>Mean</b>	49.81	49.22	48.74	48.86
<b>Standard deviation</b>	3.79	3.66	3.81	3.95
<b>Minimum</b>	45.2	44.5	44.4	44.4
<b>Maximum</b>	59.1	55.6	56.1	56.7

N\*= Number of cases

The preoperative mean K1 was 49.81 ( $\pm 3.79$ ), with a minimum of(45.2) ,and maximum of (59.1) . At 1 month postoperative; the mean K1 was 49.22 ( $\pm 3.659$ ), with a minimum of (44.5),and maximum of(55.6). At 3 months postoperative; the mean K1 was 48.744( $\pm 3.81$ ), with a minimum of(44.4),and maximum of(56.1). At 6 months postoperative; the mean K1 was 48.86( $\pm 3.946$ ), with a minimum of (44.4), and maximum of (56.7).

**Figure 4: The changes in topographic measurements over time.**

**K=keratometry**

There was a significant decrease in the mean K1 value between preoperative & 6 months postoperative ( $p < 0.05$ ). There was also a significant decrease in the mean K1 at 1 month & 3 months respectively ( $p < 0.05$ ).

The K1 value decreased by 1D or more in 24 eyes (80%) & remained unchanged in 4 eyes (13.33%) & it increased by 1D in 2 eyes (6.66%). (Fig. 4) (Table 5).

### **b) Changes in K2:**

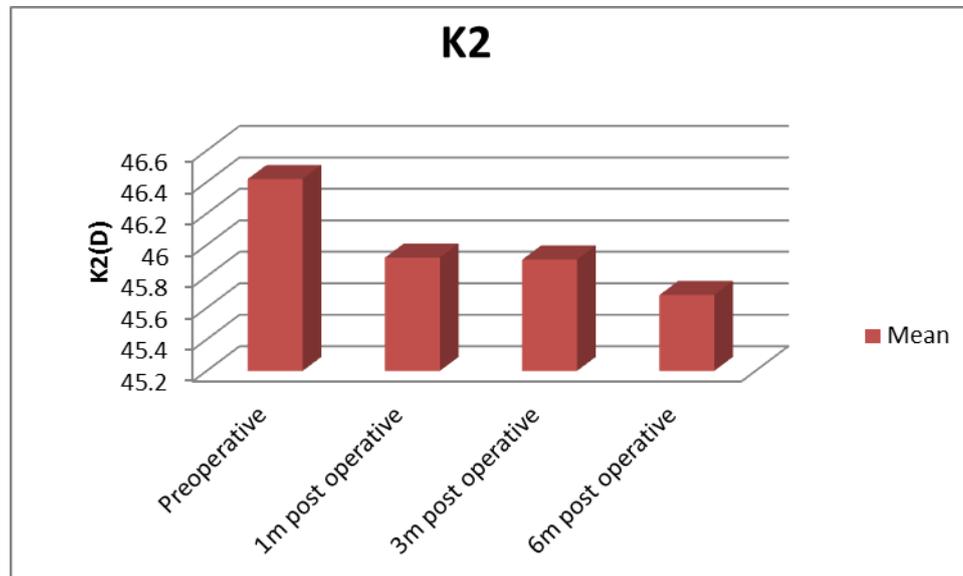
**Table (6): (K2) before and after CXL treatment.**

<b>K2 (Diopter)</b>	<b>Preoperative (n*=30)</b>	<b>Postoperative</b>		
		<b>1 month (n*=30)</b>	<b>3 month (n*=29)</b>	<b>6 month (n*=28)</b>
<b>Mean</b>	46.42	45.92	45.91	45.68
<b>Standard deviation</b>	3.09	3.03	3.09	3.20
<b>Minimum</b>	43	41.1	41	41
<b>Maximum</b>	53.2	53.8	53.6	53.6

N\*= Number

The preoperative mean K2 was 46.42 ( $\pm 3.086$ ), with a minimum of (43), and maximum of (53.2). At 1 month postoperative; the mean K2 was 45.92 ( $\pm 3.029$ ), with a minimum of (41.1), and maximum of (53.8). At 3 months postoperative ;the mean K2 was 45.9 ( $\pm 3.093$ ), with a minimum of (41) and maximum (53.6). At 6 months postoperative the

mean K2 was  $45.68(\pm 3.198)$ , with a minimum of (41), and maximum of (53.6).



**Figure 5: The changes in topographic measurements over time.**

**K=keratometry**

There was a significant decrease in the mean K2 value between preoperatively & 6 months ( $p < 0.05$ ). There was a significant decrease between baseline & 1 month & 3 months respectively ( $p < 0.05$ ). The K2 value decreased by 1 D or more in 21 eyes (70%) of patients & remained unchanged in 6 eyes (20%) of patients & it increased by 1D in 3 eyes (10%) (Fig. 5) (Table 6).

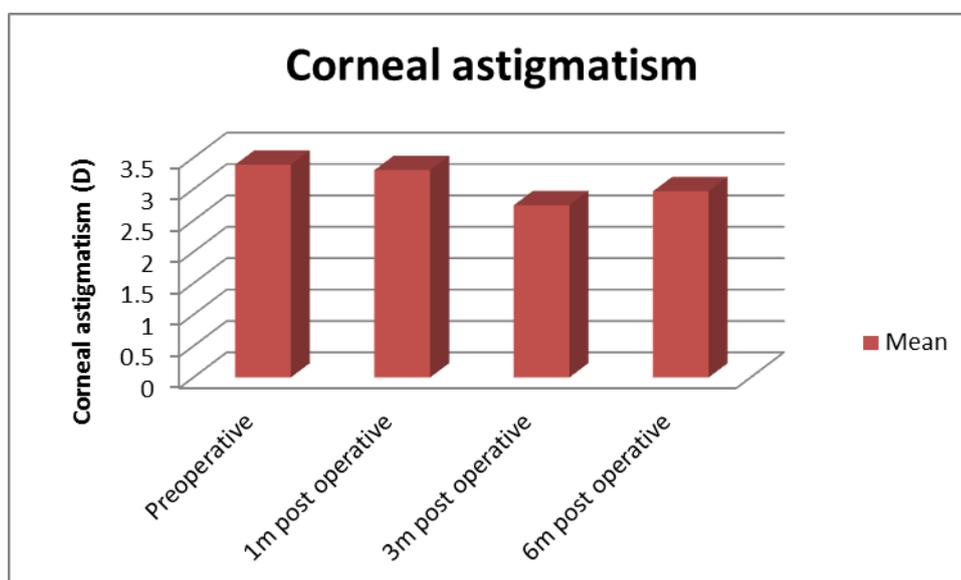
**c) Changes in corneal astigmatism (simulated keratometry):**

**Table (7): corneal astigmatism before and after CXL treatment.**

corneal astigmatism (Diopter)	Preoperative (n*=30)	Postoperative		
		1 month (n*=30)	3 month (n*=29)	6 month (n*=28)
Mean	3.39	3.25	2.80	3.0
Standard deviation	2.11	2.18	1.67	1.94
Minimum	0.4	0.1	0.1	0
Maximum	9.2	10.2	7	7.6

N\*= Number

The preoperative mean K (sim. k) was 3.39 ( $\pm 2.11$ ) with a minimum of (0.4),and maximum of (9.2). At 1 month postoperative; it was 3.25 ( $\pm 2.184$ ), with a minimum of (0.1),and maximum of (10.2).At 3 months postoperative; it was 2.803( $\pm 1.673$ ), with a minimum of(0.1), and maximum of (7).At 6 months postoperative;it was 3.003( $\pm 1.939$ ), with a minimum of (0),and maximum of (7.6).

**Figure 6: The changes in corneal astigmatism over time.**

Changes in the mean corneal astigmatism from baseline to 1 month was statistically insignificant ( $p > 0.05$ ), however the changes between baseline & 3 months & between baseline & 6 months postoperative was statistically significant ( $p < 0.05$ ), (Fig. 6) (Table 7).

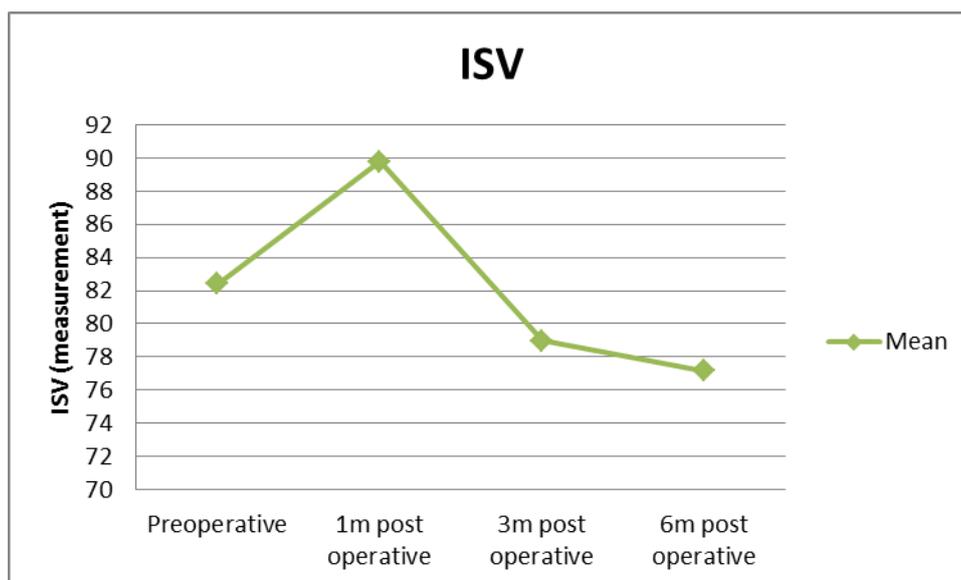
### **Changes in corneal topography indices:**

#### **A) Index of surface variance (ISV):**

**Table (8): ISV before and after CXL treatment.**

ISV	Preoperative (n*=30)	Postoperative		
		1 month (n*=30)	3 month (n*=29)	6 month (n*=28)
<b>Mean</b>	82.4	89.8	78.96	77.14
<b>Standard deviation</b>	44.57	45.3	43.33	44.09
<b>Minimum</b>	34	40	31	15
<b>Maximum</b>	201	206	192	186

The preoperative mean ISV was 82.4 ( $\pm 44.5$ ), with a minimum of(34),and maximum of(201). At 1 month postoperative; the mean ISV was 89.8 ( $\pm 45.296$ ), with a minimum of (40), and maximum of(206). At 3 months postoperative; the mean ISV was 78.965( $\pm 0.43.33$ ), with a minimum of(31),and maximum of(192). At 6 months postoperative; the mean ISV was 77.14( $\pm 44.09$ ), with a minimum of(15),and maximum of(186).



**Figure 7: Changes of ISV over time.**

At 6 months postoperatively, the mean ISV was significantly decreased from baseline ( $p < 0.05$ ). Initially, there was a significant increase in the index between baseline & 1 month ( $p < 0.05$ ) followed by a significant decrease between 1 month & 3 months ( $p < 0.05$ ) & between 3 months & 6 months ( $p < 0.05$ ) (Fig. 7) (Table 8).

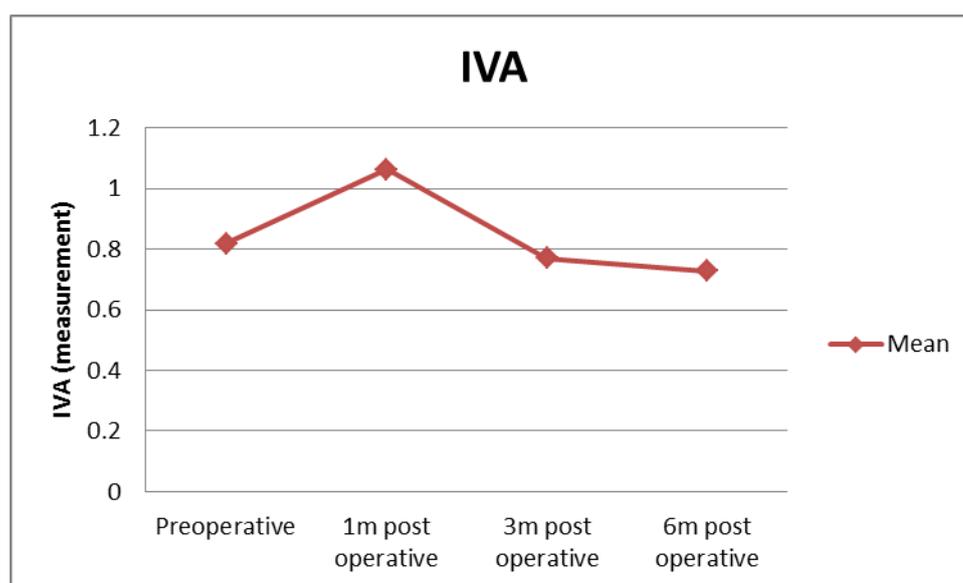
**b) Index of vertical asymmetry (IVA):**

**Table (9): (IVA) before and after CXL treatment.**

IVA	Preoperative (n*=30)	Postoperative		
		1 month (n*=30)	3 month (n*=29)	6 month (n*=28)
Mean	0.82	1.06	0.77	0.73
Standard deviation	0.57	1.02	0.55	0.55
Minimum	0.26	0.32	0.18	0.12
Maximum	2.51	5.58	2.53	2.4

N\*= Number

The preoperative mean IVA was 0.818 ( $\pm$  0.566), with a minimum of(0.26),and maximum of(2.51).At 1 month postoperative; the mean IVA was 1.06(  $\pm$ 1.023), with a minimum of (0.32), and maximum of (5.58).At 3 months postoperative; the mean IVA was 0.77( $\pm$ 0.55), with a minimum of(0.18) and maximum of(2.53). At 6 months postoperative ;the mean IVA was 0.728( $\pm$ 0.552), with a minimum of (0.12),and maximum of (2.4). At 6 months, the mean (IVA) was significantly decreased from baseline ( $p < 0.05$ ).



**Figure 8: Changes of IVA over time.**

Initially, there was a significant increase in (IVA) between baseline & 1 month ( $p < 0.05$ ) followed by a significant decrease between 1 month & 3 months ( $p < 0.05$ ) & between 3 month & 6 months ( $p < 0.05$ ). (Fig. 8) (Table 9)

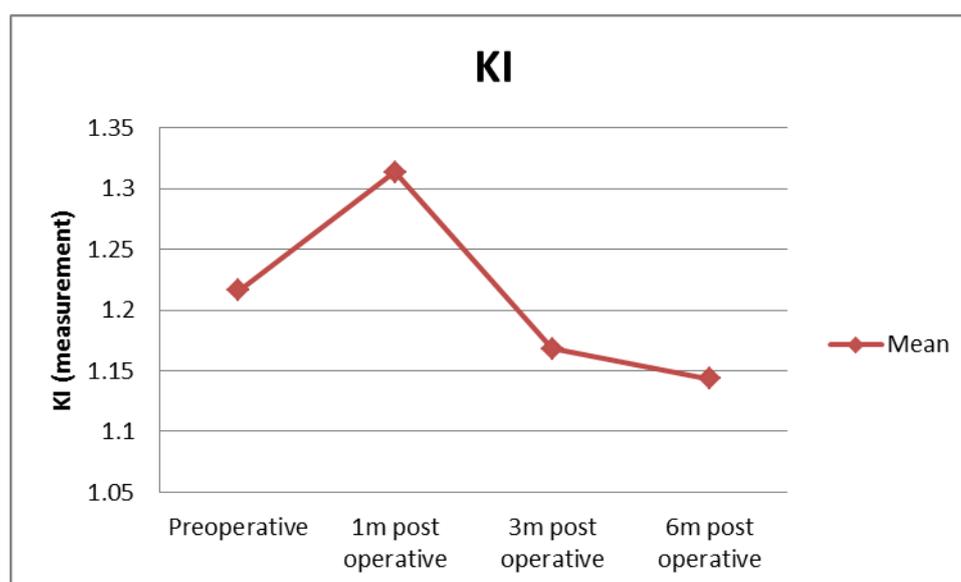
### c) Keratoconus index (KI):

**Table (10): (KI) before and after CXL treatment.**

KI	Preoperative (n*=30)	Postoperative		
		1 month (n*=30)	3 month (n*=29)	6 month (n*=28)
<b>Mean</b>	1.22	1.31	1.17	1.14
<b>Standard deviation</b>	0.16	0.15	0.17	0.19
<b>Minimum</b>	1.06	1.1	0.9	0.8
<b>Maximum</b>	1.73	1.76	1.76	1.72

N\*= Number

The preoperative mean KI was 1.216(  $\pm$  0.158), with a minimum of(1.06),and maximum of(1.73).At 1 month postoperative; the mean KI was 1.313(  $\pm$ 0.146), with a minimum of(1.1), and maximum of (1.76) . At 3 months postoperative; it was 1.168( $\pm$ 0.168), with a minimum of(0.9) and maximum of(1.76) . At 6 months postoperative; it was 1.432( $\pm$ 0.188), with a minimum of (0.8),and maximum of (1.72).

**Figure 9: Changes of KI over time.**

At 6 months (KI) was significantly decreased over baseline ( $p < 0.05$ ). Initially, there was a significant increase in the index between baseline & 1 month ( $p < 0.05$ ) followed by a significant decrease between 1 month & 3 months ( $p < 0.05$ ) & between 3 months & 6 months ( $p < 0.05$ ). (Fig. 9) (Table 10)

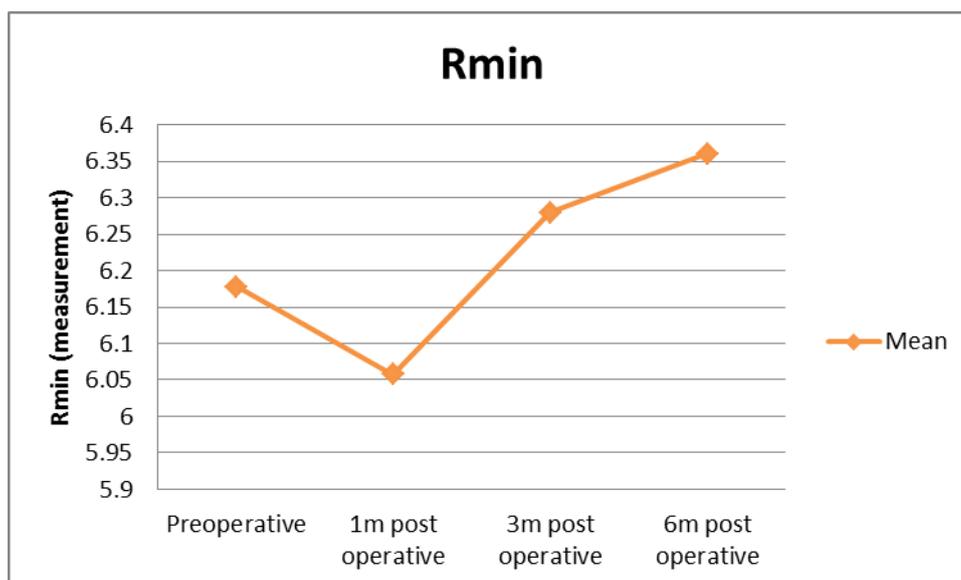
**d) Minimum radius of curvature (Rmin):**

**Table (11): (Rmin) before and after CXL treatment.**

<b>Rmin</b>	<b>Preoperative (n*=30)</b>	<b>Postoperative</b>		
		<b>1 month (n*=30)</b>	<b>3 month (n*=29)</b>	<b>6 month (n*=28)</b>
<b>Mean</b>	6.18	6.06	6.28	6.36
<b>Standard deviation</b>	0.68	0.76	0.72	0.77
<b>Minimum</b>	5.2	4.4	5.1	5.1
<b>Maximum</b>	7.2	7.1	7.3	7.4

N\*= Number

The preoperative mean Rmin was 6.178 ( $\pm 0.683$ ), with a minimum of(5.2),and maximum of (7.2).At 1 month postoperative; it was 6.057 ( $\pm 0.756$ ), with a minimum of(4.4),and maximum of (7.1).At 3 months postoperative; it was 6.279( $\pm 0.715$ ), with a minimum of(5.1) and maximum of (7.3).At 6 months postoperative; it was 6.360( $\pm 0.766$ ), with a minimum of(5.1),and maximum of (7.4).



**Figure 10: Changes of Rmin over time.**

At 6 months, the minimum radius of curvature was significantly increased (that is, the cornea was flattered) from baseline ( $p < 0.05$ ). Initially, there was a significant decrease in (Rmin) between baseline & 1 month ( $p < 0.05$ ) followed by a significant increase between 1 month & 3 months ( $p < 0.05$ ) & between 3 months & 6 months ( $p < 0.05$ ) (Fig. 10) (Table 11)

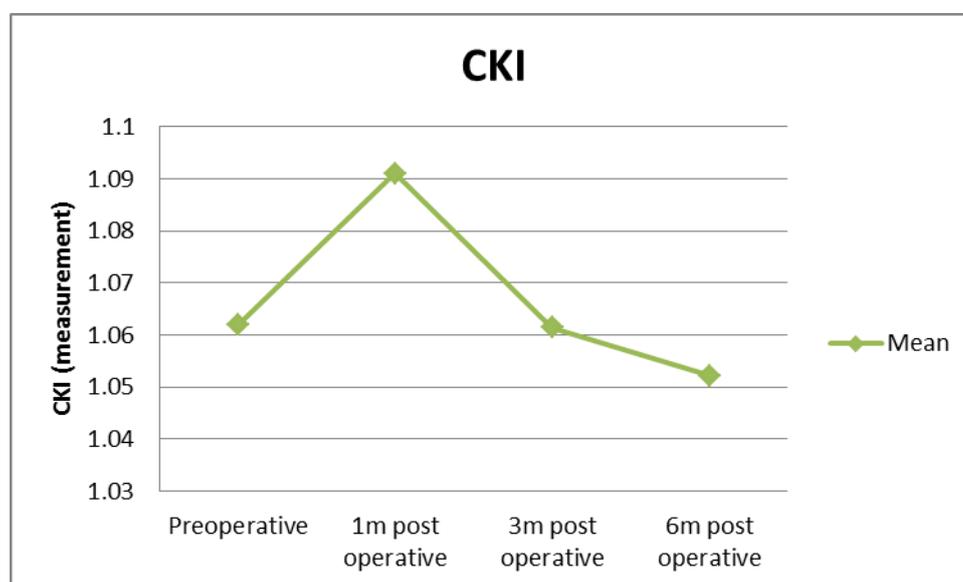
**e) Central keratoconus index (CKI):**

**Table (12): (CKI) before and after CXL treatment.**

CKI	Preoperative (n*=30)	Postoperative		
		1 month (n*=30)	3 month (n*29)	6 month (n*=28)
Mean	1.06	1.09	1.06	1.05
Standard deviation	0.04	0.08	0.05	0.05
Minimum	1.01	1.02	0.98	0.97
Maximum	1.15	1.4	1.16	1.15

N\*= Number

The preoperative mean CKI was 1.061 ( $\pm 0.044$ ), with a minimum of (1.01), and maximum of (1.15). At 1 month postoperative; it was 1.091 ( $\pm 0.077$ ), with a minimum of (1.02), and maximum of (1.4). At 3 months postoperative; it was 1.061 ( $\pm 0.051$ ), with a minimum of (0.98) and maximum of (1.16). At 6 months postoperative ;it was 1.052 ( $\pm 0.049$ ), with a minimum of (0.97) and maximum of (1.15).



**Figure 11: Changes of CKI over time.**

At 6 months, the (CKI) was slightly decreased from baseline , ( $p < 0.05$ ). (Fig. 11) (Table 12)

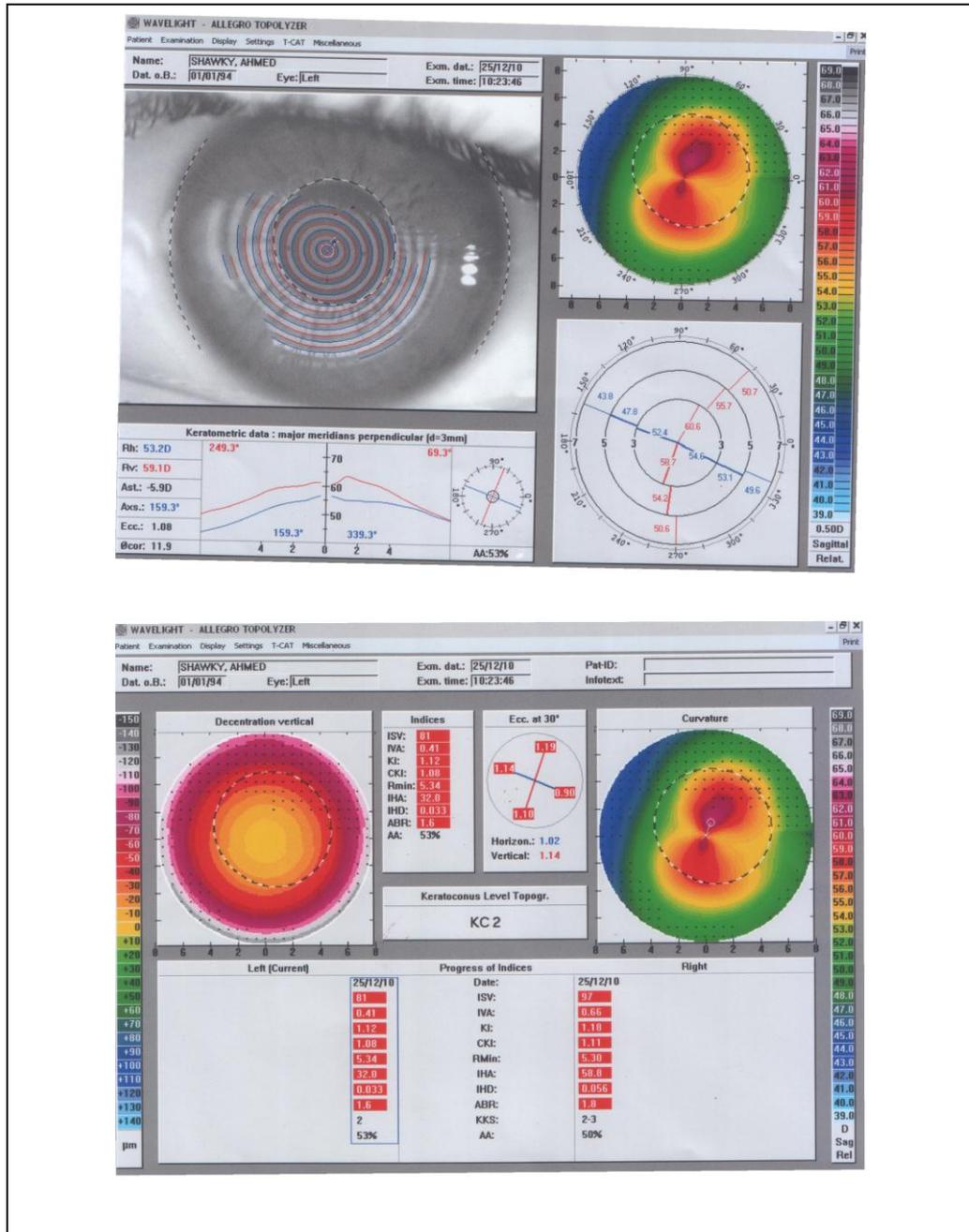


Figure 12: (Case No.1) preoperative corneal topography

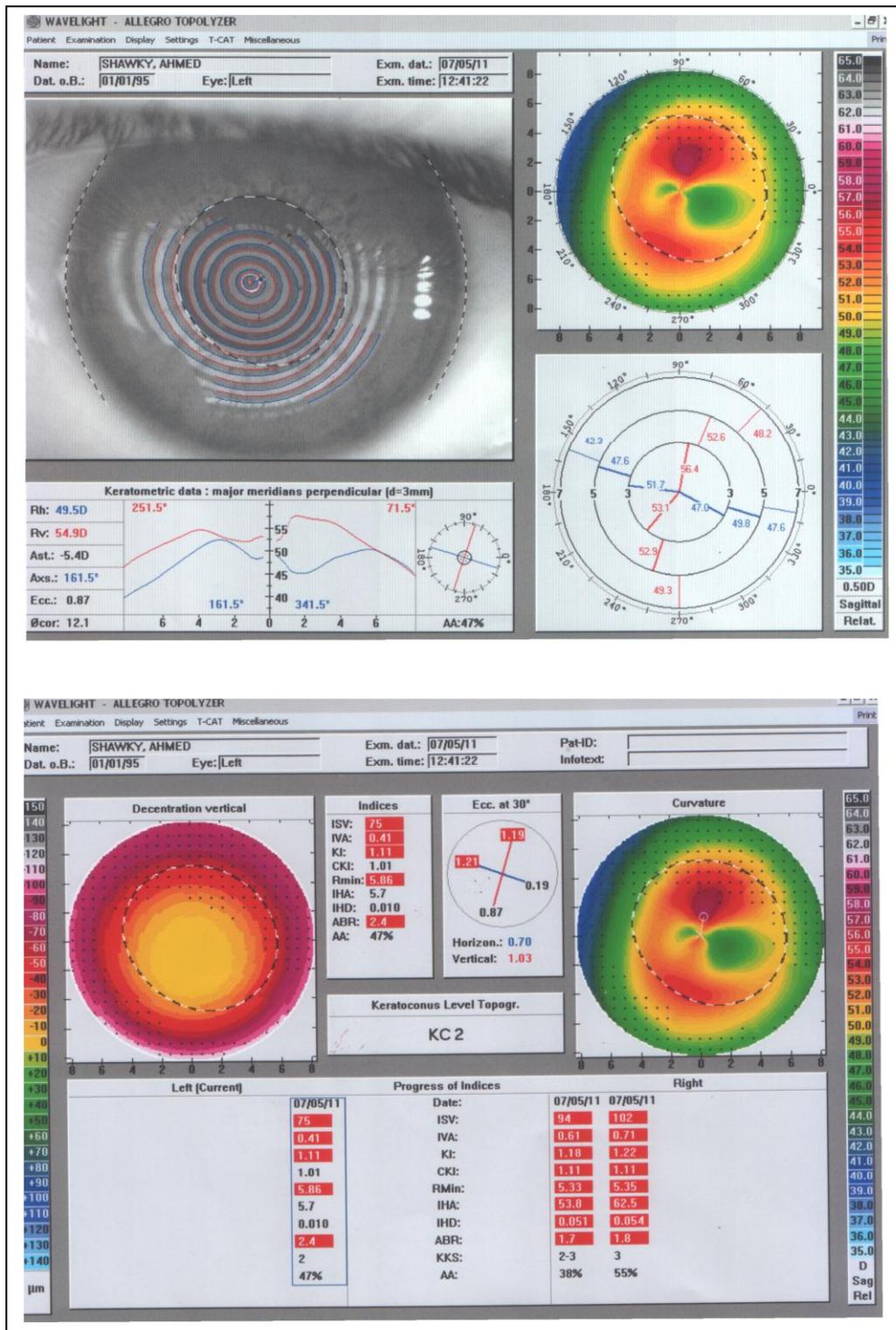


Figure 13: (Case No.1) postoperative corneal topography

Figure 12 and 13 show the pre and postoperative corneal topography of some patient, in whom we can notice the improvement in the corneal indices.

The improvement in corneal topography indices at 6 months after (CXL) is suggestive of an overall improvement in corneal shape.