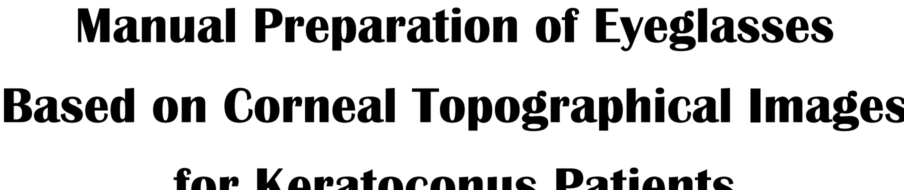

Manual Preparation of Eyeglasses Based on Corneal Topographical Images for Keratoconus Patients

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التحضير اليدوي للنظارات بناءً على الصور الطبوغرافية للقرنية لمرضى القرنية المخروطية

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Abstract

Keratoconus (KCN) is a non-inflammatory, progressive thinning process of the cornea. It is considered one of the advanced biomechanical changes on the corneal surface, and methods of treatment in late cases are special designed contact lenses or surgical intervention. The objective of this paper is to customize the standard eyeglass lens in a way so that it fits with the abnormal shape and changes of the surface of the cornea of a patient suffering from KCN disease.

The proposed method here, based on manual scratching of the external surface of the standard eyeglass lens under supervising of an expert optometrist, where this method is considered as a less expensive and safer. Retrospectively, a nine cases measured before in Al-Amal Center, Baghdad, Iraq and diagnosed with KCN severity using topographical mapping.

A zero-lens was assigned to each patient and it was scratched using CC2000 scratch paper. Then the thickness of the lens was measured before and after scratching in the center of the lens and in four different locations of the topography map with dial gage indicators. After that, the results were compared between the manually scratched lens and the topography map of each patient and evaluate the extent of the match between them. The results of this study are that two types of samples were isolated, in the first type the measurements are close between the topography maps of the patient and the measurements on a regular basis from the side of the behavior of the surface with a difference (0.059 - 0.94)

As for the second type, points were obtained that moved away from the real behavior of the photographic image, then it was necessary to isolate it and use the values next to it.

Keywords: Refractive error (RE) , Keratoconus (KCN), Pentacam, Topography Maps.

المستخلص

القرنية المخروطية (KCN) هي عملية ترقق تدريجية غير التهابية في القرنية. تعتبر من التغيرات الميكانيكية الحيوية المتقدمة على سطح القرنية ، وطرق العلاج في الحالات المتأخرة هي العدسات اللاصقة المصممة بشكل خاص أو التدخل الجراحي. الهدف من هذه الورقة هو تخصيص عدسة النظارات القياسية بطريقة تتناسب مع الشكل غير الطبيعي والتغيرات في سطح قرنية المريض المصاب بمرض KCN.

تعتمد الطريقة المقترحة هنا على الخدش اليدوي للسطح الخارجي لعدسة النظارات القياسية تحت إشراف أخصائي بصريات خبير ، حيث تعتبر هذه الطريقة أقل تكلفة وأكثر أمانًا. بأثر رجعي ، تم قياس تسع حالات من قبل في مركز الأمل ، بغداد ، العراق وتم تشخيصها بخطورة KCN باستخدام الخرائط الطبوغرافية.

تم تخصيص عدسة صفرية لكل مريض وتم خدشها باستخدام ورق خدش CC2000. ثم تم قياس سماكة العدسة قبل وبعد الخدش في وسط العدسة وفي أربعة مواقع مختلفة من الخريطة الطبوغرافية مع مؤشرات قياس القرص. بعد ذلك تمت مقارنة النتائج بين العدسة المخدوشة يدويًا وخريطة الطبوغرافيا لكل مريض وتقييم مدى التطابق بينهما. نتائج هذه الدراسة تم عزل نوعين من العينات ، في النوع الأول تكون القياسات متقاربة بين الخرائط الطبوغرافية للمريض والقياسات بشكل منتظم من جانب سلوك السطح مع اختلاف (0.059) - 0.94)

أما النوع الثاني فقد تم الحصول على نقاط ابتعدت عن السلوك الحقيقي للصورة الفوتوغرافية ، فكان من الضروري عزلها واستخدام القيم المجاورة لها.

1 - Introduction

One of the most prevalent eye conditions in children and adolescents and a major global public health problem is refractive error (RE). According to reports, RE is to blame for 42% of vision impairments worldwide [1]. Children who are exposed to RE may experience pathologic ocular changes like myopic macular degeneration and retinal detachment, which could result in irreversible blindness. In addition, RE has a significant impact on children's psychosocial well-being, which may have an adverse effect on their educational outcomes and educational opportunities. When the eye's shape prevents light from concentrating directly on the retina, refractive errors arise. Refractive errors can be brought on by changes in the cornea's shape, age of the lens, or the length of the eyeball (longer or shorter). [2]. the three types of refractive error are myopia, hyperopia, and astigmatism. Light rays from an object at infinity are focused in front of the retina in myopia and behind the retina in hyperopia, but they do not focus at a single spot in astigmatism due of differences in the cornea's or lens's curvature at various meridians [3].

Eye disorders are regarded as a serious health issue. The eye condition KCN causes the cornea to gradually curve, changing its symmetrical dome shape to an asymmetric cone. This condition is accompanied by blurred vision due to irregular astigmatism [4]. It results in decreased visual acuity and a change in spectacles. While there are numerous tools available to aid in the diagnosis of KCN, Pentacam is one of the most effective ones since it can provide readings and maps that show the condition of the cornea [5]. The four refractive maps, which are made up of four maps, are the maps that aid in the detection of KCN (Sagittal, Pachymetry, Elevation front and Elevation back maps). Each map provides a number of factors, which can be retrieved individually or together in a single image. The

ophthalmologists will then make the final determination after reviewing all of the components that were collected from the four refractive maps [6]. In some abnormal cases the biomechanical of the cornea distorted in a way that the corneal shape became irregular with a vision lose, due to the KCN diseases. Surgical options for KCN aim to alter the disease's natural course and improve vision, whereas non-surgical options aim to improve vision without causing damage to the ocular surface. In the majority of patients with keratoconus, contact lenses and glasses are the standard non-surgical treatment for vision rehabilitation. Treatment also incorporates cutting-edge surgical procedures like anterior lamellar keratoplasty, corneal cross-linking (CXL), intra-stromal rings and refractive lens exchange of intraocular lens implantation. Today, there is widespread agreement that contact lenses play the most significant role in KCN patients' visual rehabilitation [7]. Since contact lenses alter the ocular surface even in non-keratcounus individuals, the application of contact lenses for KCN patients ought to focus primarily on improving visual acuity without jeopardizing the health of the cornea and ocular surface [8]. The practitioner must select a lens fitting that does not compromise the health of the anterior ocular surface, despite the patient's need for clear vision and comfort with the lens. As a result, the procedure frequently takes a long time and is challenging for both the patient and the eye doctor. Because of the way KCN is treated with long-term contact lenses.

In addition to the severity of the KCN, the patient's visual needs, comfort, and contact lens tolerance are taken into consideration when selecting a pair of lenses. Large diameter RGP lenses, scleral lenses, hybrid lenses, and keratcounus-specific soft lenses are just a few of the contact lens options available to patients with corneal irregularities thanks to recent advancements in design and features. According to new data, hybrid lenses, special design

contact lenses, and new design scleral lenses offer superior comfort and visual acuity to conventional RGPs(rigid gas permeable lenses) [9, 10].

In the present study, an eyeglass with no lens power on it used to compensate the abnormality of the corneal surface for patient with KCN. To do this scratching for the outer surface of the Plano lens is done manually under supervising of an expert optometrist. The scratched area selected from the topographical imaging of patients measured on Al Amal center, Baghdad, Iraq. Nine images from different nine cases are selected after consulting ophthalmologist.

2 - Materials and Methods

In this study, glasses were manufactured for patients with keratoconus (KCN) using the manual method, first step was Preparation of the sample (lenses) which is zero convex lens, 2mm thickness and 60mm diameter. Second step is Collect the topography map for the patient using pentacam, as shown in Figure (1).

Corneal topography produces many results in graphical and parametric shape. The most important reference graph is the 4 – refractive maps, which considered as the golden standard for the clinical diagnosis of corneal conditions. Third step scratched the sample according to topography maps for the patient using scratching paper CC 2000, final step was measuring the thickness of the sample before and after scratching using dial gage indicators in the center of lenses and in the four different positions that change according to the topography maps for each patient and these points have been selected on the steep and felt axes intersection with contour of 6mm as shown in Figure (2). Then comparing the results of manual work with the results of corneal topography and evaluation

the similarity ratio between them by using different equation (linear, polynomial 2nd degree, polynomial 3rd degree, logarithm, exponential). Depending on the result obtained from this equations and calculation the polynomial 2nd degree was the best choice in terms of matching between manual measurements and topography maps for patient. To evaluate the resulted scratched lenses, the below procedure of work have been followed:

1. Under supervising of the ophthalmologist a four nodes on each image has been selected well, to be the most dominated points on the surface of the KCN patient.
2. The sagittal map (for each case) has been printed out on a transparent paper (with scale of 1:2) and finally paste it on the outer surface of Plano power lens, under supervising of an optometrist.
3. According to the rules followed by optometrist to prepare lens for patient glass the scratched surface is the inner surface of the lens.
4. The four selected points on the upper topography map as mentioned on point 1, have been reselected of the pasted paper to be guide of work during the manual scraping.
5. The depth per color on the topographical images are guided as on the original scale of the right hand side of each images.
6. After the manual scratching of the lenses a measurement for the final product have been done both manually using (dial gage indicators) and back to the topography to evaluate the final resulted lens.
7. For comparison and to evaluate the accuracy of the procedure done the four selected nodes as mentioned in point 4 have been checked both manually and topographically and the differences have been studied.

Fig. 1: The topography maps for the patients

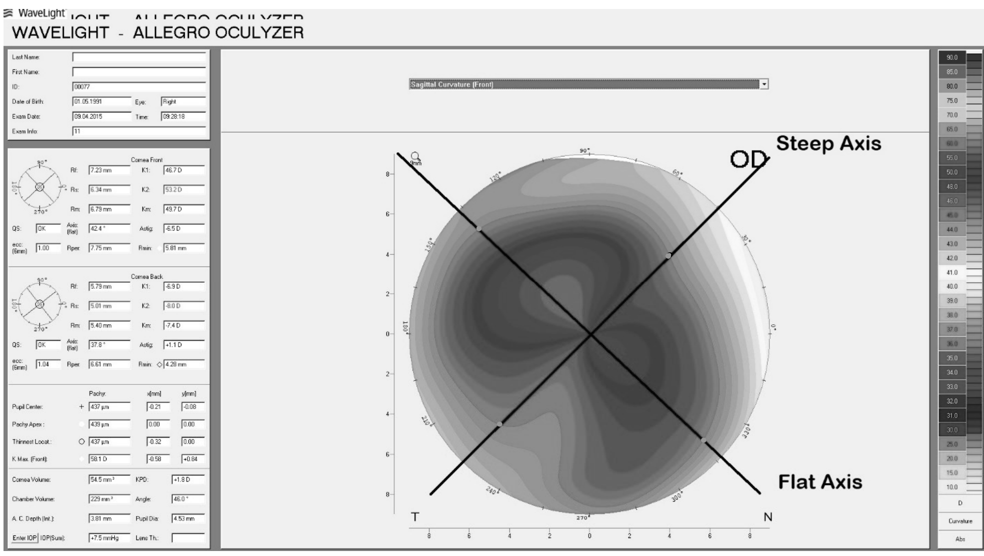


Fig. 2: Flat and Steep Axes

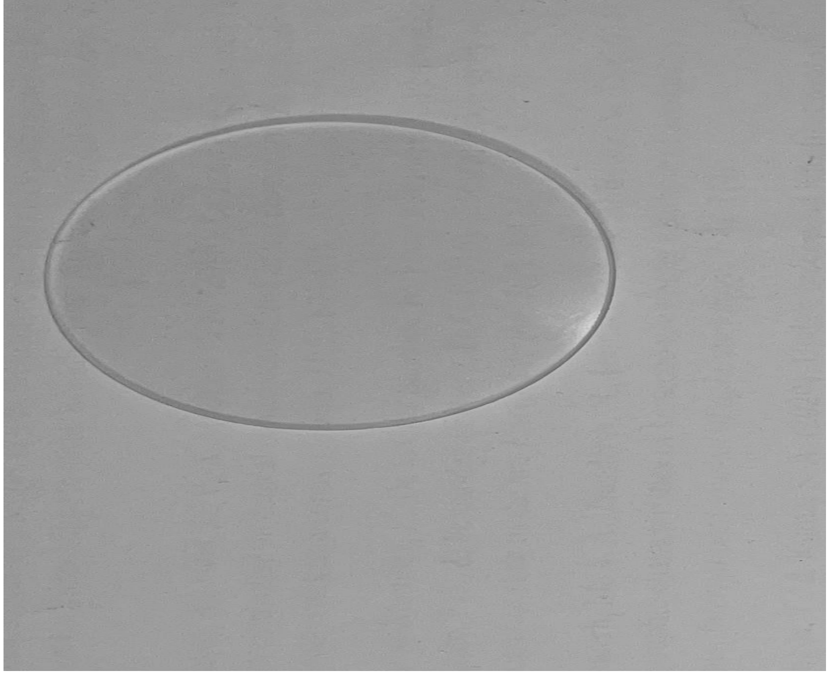


Fig. 3: Picture before scratching

Table (1) Represent, samples were taken (zero lenses) and the thickness of the lens was measured before and after scratching in the center of the lenses and in 4 different positions of the topography which is changes according to each patient.

No.	No. of scratch	Picture after scratching	Thickness in center of sample	Thickness in bowtie	Thickness in the shape
1	time 25		1.967	1.976	First point:1.941 Second point:1.949 Third point:1.976 Fourth point:1.844
2	time 20		1.926	1.921	First point:1.907 Second point:1.778 Third point:1.849 Fourth point:1.913
3	time 15		2.173	2.173	First point:2.177 Second point:2.107 Third point:2.043 Fourth point:2.072
4	time 30		1.879	1.856	First point:1.885 Second point:1.987 Third point:2.011 Fourth point:1.891
6	time 20		2.186	2.186	First point:2.103 Second point:2.145 Third point:2.177 Fourth point:2.107
7	time 25		2.059	2.059	First point:1.961 Second point:1.999 Third point:2.09 Fourth point:2.153
8	time 15		2.141	2.141	First point:2.205 Second point:2.106 Third point:2.141 Fourth point:2.057
9	time 35		1.962	1.903	First point:1.983 Second point:1.83 Third point:1.878 Fourth point:2.005

Table (2) Thickness before and after scratching

Hint: thickness of eye glasses lenses before scratching 2.049

3 - Results and Discussion

The case studies used in the present work, have been collected, retrospectively, from patients measured and diagnosed by an ophthalmologist from Al-Amal Center, Baghdad Iraq. Each one of them undergoes number of measurements including: objective and subjective refraction errors assessment, and corneal topography using Pentacam device (Oculus GmbH, Wetzlar, Germany). The medical history records have been ethically approved to be used in our study from the center under the supervising of the chief ophthalmologist of the center. The interesting images collected from the topographer include the sagittal curvature maps for each 9 cases selected.

To check the results a comparison between the manual and topographical procedure have been done (as mentioned on the procedure of work previously). The relationship between these two groups of measurements have been plotted on an x-y coordinate system and find the best curve fitting function for both measurements with the same degree of complexity.

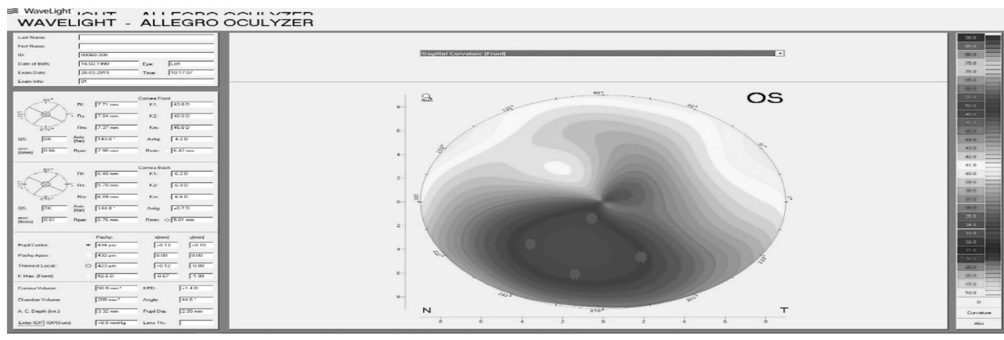
In general, and based on above procedure a group of four relations have been recognized here, these groups are:

1. Cases number 2, 5, 6, 8 and 9 shows very good agreement in shape and trend behavior. That looks both with simple drift difference where the topographical measurements always more than the manual measurements once with increments ranged as (0.279, 0.958, 0.212, 0.172 and 0.196). Also, it is true to say that the overall behaviors of the cases are more relax in changes that their slope are close to the horizon. Clinically this good agreement comes from the truth that the cases here are with a dominated one-part

bowtie steepening either on the inferior part of the eye as in cases (2, 5 and 9) or superiorly in case 8, while case 6 is the only case with temporal steepening. Although there is difference in steepening positions but still we can some etiological effect of the KCN of the other part of the eye that finally give an optical semi-balanced for the final visual acuity.

2. Case number 1 shows a typical sensitive drift for the difference between the two methods. In such type of drift, two edges are specified. A leading edge on the right, where the difference close to zero (such as in point 1 to the right of the curves) and tail edge on the left, where the difference in its maximum value. Still the manual measurements here parallel to the horizon (and considered as reference) while the topographical measurement have an angle of (25◦) with the reference measurement. The bowtie shape here is totally on the inferior part of the eye and causing an elevation on this part of the eye more than the posterior side that the topographical system measures it as a coma toward the superior. This imbalance between the quarters present such condition of measurements.
3. Cases 3 and 4, backs with difference fluctuated on the middle points more than on points 1 and 4, where these two points (1 and 4) still have good agreement with each other’s.
4. Case number 7 shows a typical sensitive drift for the difference between the two methods. The bowtie shape here is abnormal and sever with oblique position of 19.8◦ astigmatism

5. the manual measurements converge the topographical at point (1) with simple offset Δ=0.059 and then gradually move away in the point (4) with an offset Δ=0.17 To evaluate the extent of the match between the manual measurements of lenses and topography maps of the patients that was obtained from pentacam for each case. The polynomial 2nd degree equations were used to draw the curves as shown in Figs.4, 5, 6, 7, The blue curve represent the manual measurements, while the red one represent the topography measurements and according to behaviors of the curve the cases categories into four groups, 1st group included case 2, 5, 6, 8 and 9 as shown in Fig. 4 (a, b, c, d, e).



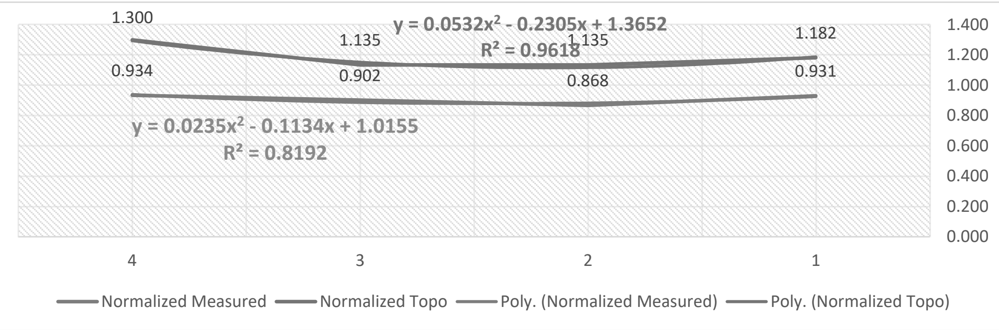
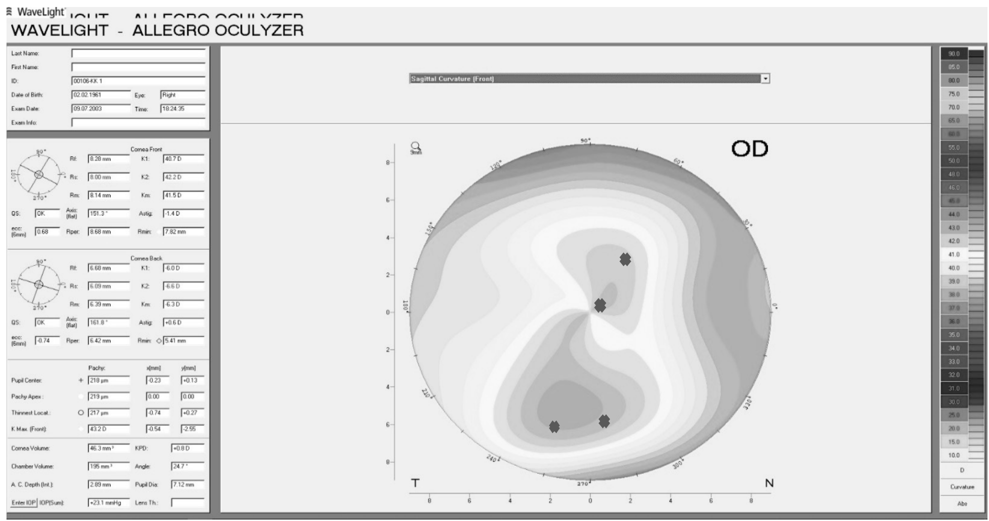


Fig. 4a (case2)



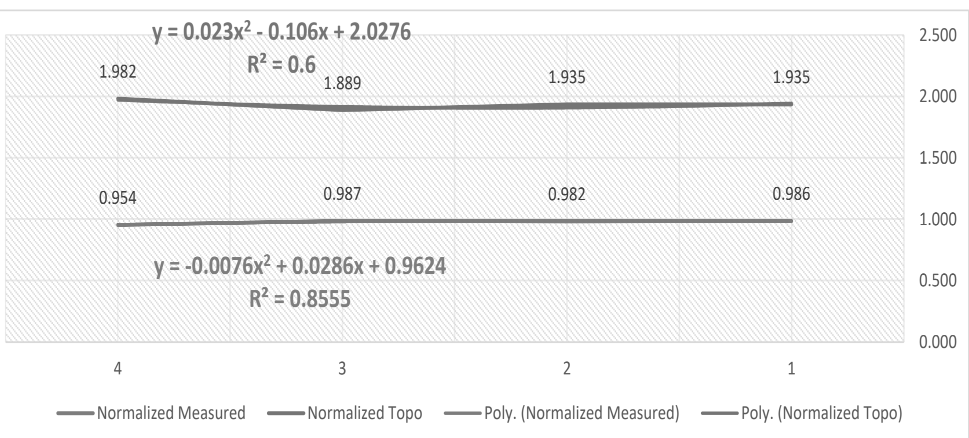
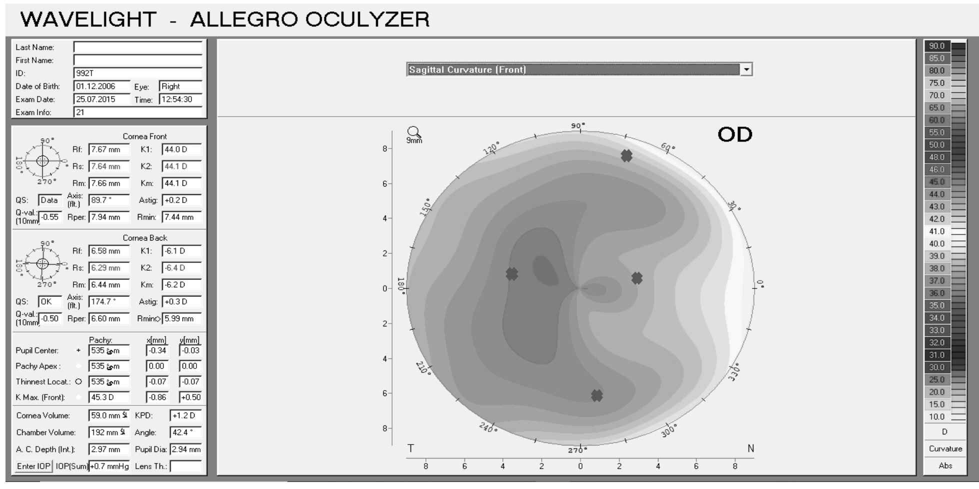


Fig. 4b (case5)



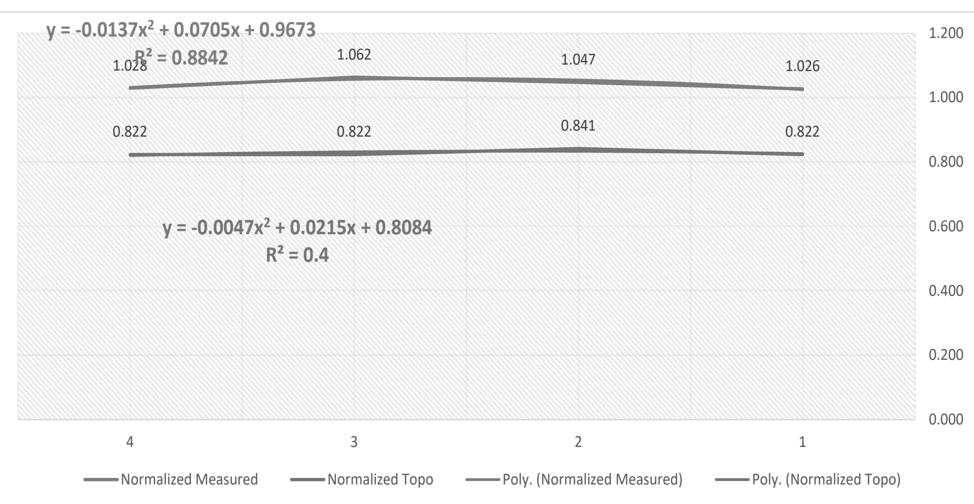
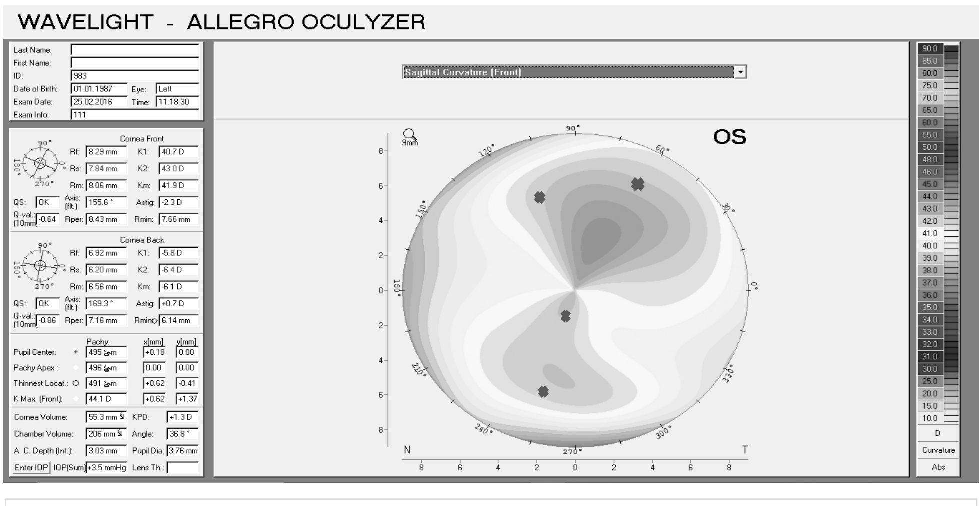


Fig. 4c (case6)



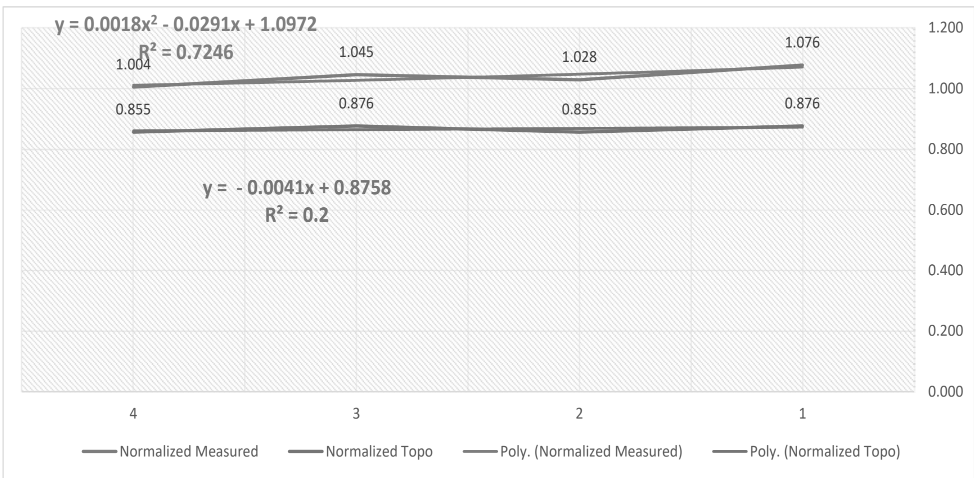


Fig. 4d (case8)

Fig. 4e (case9)

According to first group: Back to the shape of the curve , simply change has been observe in the curve after point 3.Results here shows very good agreement between manual measurement and topography that the change in two curves here show identical slope.

According to second group: included only one (case 1) as shown in Fig 5, this case been diagnosed as keratoconus with sever steeping on the inferior part away from contact of cornea. Results here Shows very good agreement between measurement and topography with offset Δ=0.27.and the shape of the curve shows gradually and smooth variation start from point 1 to 4 with a total slop of 25◦

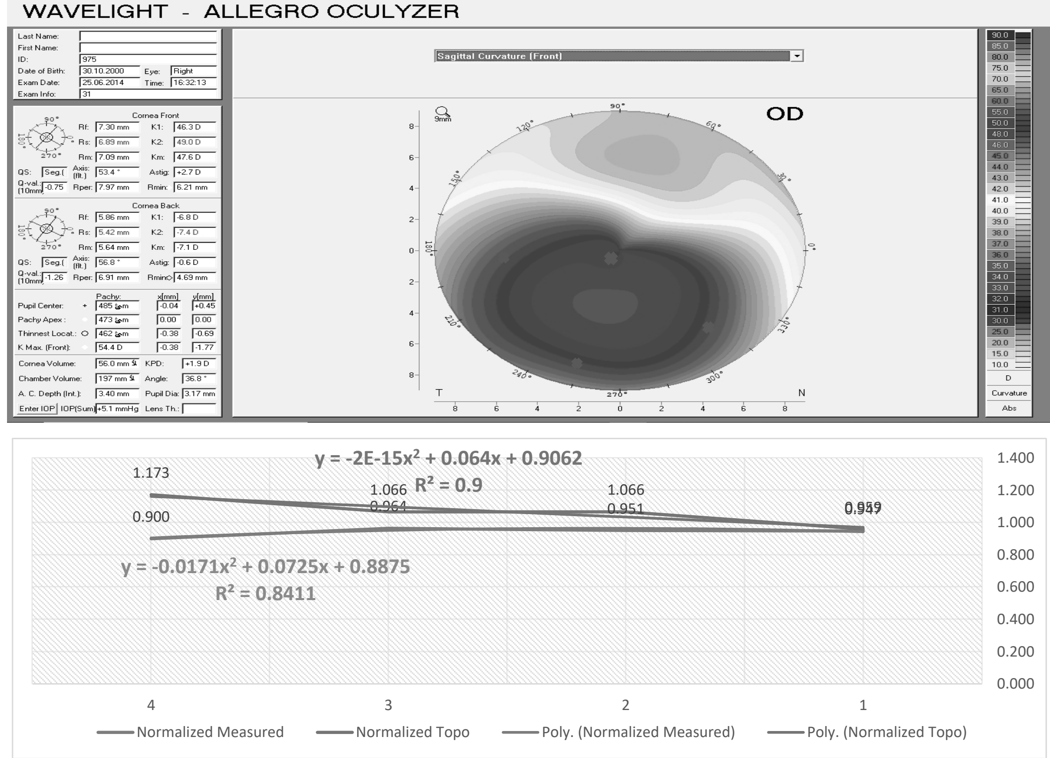


Fig 5 (case1)

According to third group: included case 3 and case 4 as shown in Fig. 6(a,b), in the case 3 the patient Clinically has been an abnormal and sever bowtie with oblique position of 42◦ astigmatism(from the table left

of the topography map), but the case 4 has been diagnosed as keratoconus with sever steeping on the inferior part away from contact of cornea. Back to the shape of curve the differences between two curves appears mostly in points 2 and 3 .While the start and end points 1 and 4 are more close and same in behavior as in case 1 and 2.

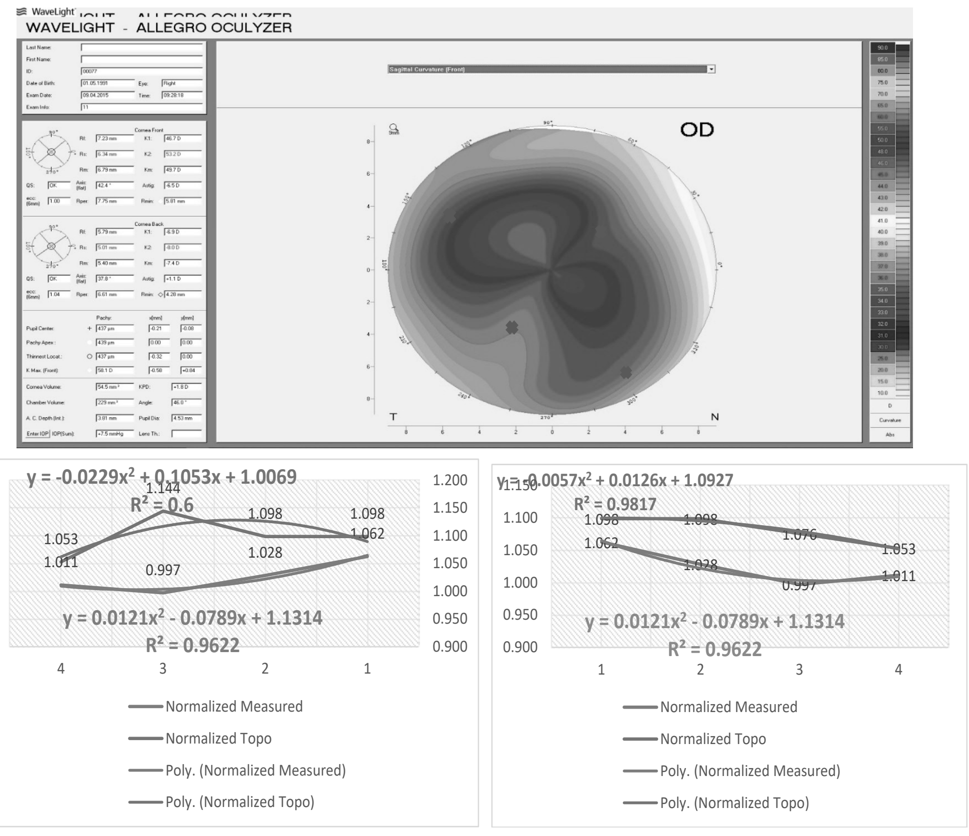


Fig. 6a (case3)

Fig. 6b (case4)

According to fourth group: included case 7 as shown in Fig. 7, clinically the patient has been an abnormal and sever bowtie with oblique position of 19.8◦ astigmatism (from the table left of the topography map). The two curve (measurement and topography) converge at point (1) with simple offset Δ=0.059 and then gradually move away in the point (4) with an offset Δ=0.17

WAVELIGHT - ALLEGRO OCULYZER

Last Name:			
First Name:			
ID:	983		
Date of Birth:	01.01.1987	Eye:	Right
Exam Date:	02.07.2014	Time:	14:09:24
Exam Info:	11		

Cornea Front

Rf:	8.27 mm	K1:	40.8 D
Rs:	7.63 mm	K2:	44.3 D
Rm:	7.95 mm	Km:	42.5 D
QS: OK	Axis: (flt.) 19.8 °	Astig:	-3.5 D
Q-val. (10mm): -0.66	Rper: 8.32 mm	Rmin:	7.51 mm

Cornea Back

Rf:	6.74 mm	K1:	-5.9 D
Rs:	6.14 mm	K2:	-6.5 D
Rm:	6.44 mm	Km:	-6.2 D
QS: OK	Axis: (flt.) 16.2 °	Astig:	+0.6 D
Q-val. (10mm): -0.70	Rper: 7.05 mm	Rmin:	6.03 mm

	Pachy:	x[mm]	y[mm]
Pupil Center:	491 µm	-0.19	+0.05
Pachy Apex:	492 µm	0.00	0.00
Thinnest Locat.:	490 µm	-0.29	-0.29
K Max. (Front):	44.9 D	-0.14	+0.43

Cornea Volume:	55.2 mm³	KPD:	+1.2 D
Chamber Volume:	201 mm³	Angle:	37.7 °
A. C. Depth (Int.):	3.07 mm	Pupil Dia:	3.72 mm
Enter IOP	IOP(Sum): +3.8 mmHg	Lens Th.:	

Sagittal Curvature (Front)

OD

$y = 0.0031x^2 + 0.0173x + 0.9347$

$R^2 = 0.9856$

$y = -0.0102x^2 + 0.0429x + 0.8673$

$R^2 = 0.9$

	4	3	2	1
Normalized Measured / Normalized Topo (upper)	1.051	1.020	0.976	0.957
Normalized Measured / Normalized Topo (lower)	0.878	0.898	0.918	0.898

Normalized Measured — Normalized Topo — Poly. (Normalized Measured) — Poly. (Normalized Topo)

Fig. 7 (case7)

4 - conclusion

Manual method can be used to treat the vision problem of a patient with keratoconus by scratching the eye glasses lenses according the topography maps of the patient. The polynomial 2nd degree equation was the best choice in terms of matching between manual measurements and topography maps for patient ,that was achieved from a set of equations (linear, polynomial 2nd degree, polynomial 3rd degree, logarithm,exponational),depending on the results from this equation curves were drawn representing manual and topography measurements.

The cases were classified into four groups according to the behavior of the curves (manual and topography), which the first group includes 5 cases, second group includes one case, third group includes two cases, and the fourth group includes one case.

After studying and analyzing all cases according to its behavior, it was found that the second group (which includes case No. 1), was showing the best and agreement between manual and topography measurements obtained.

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