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ORTHOKERATOLOGY
CORNEAL CURVATURE CHANGES IN RELATIONSHIP TO VISUAL ACUITY
(INTERIM REPORT OF A FIVE YEAR STUDY)

BY

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In re-stating the purpose of Orthokeratology, it is hoped this report will stimulate more research into the area of prevention and correction of myopia through the use of contact lenses. Systematically and purposely designing contact lenses to change corneal curvatures will result in emmetropization of the eye as applied to myopes, hyperopes and astigmats. Contactologists must have a familiarity with the latest techniques and procedures for complete contact lens care of patients. Parents of a young incipient or progressive myope are no longer satisfied to watch vision deteriorate, while glasses prescribed necessarily become stronger during the most developmental period, from ten to twenty years of age. Barraquer [1], Jessen [2], Rossenwasser [3], Neilson, May and Grant [4], Hirsch [5] and Ziff [6] all tend to show that myopia can be retarded partially or completely to varyng degrees. The extent of permanent improvement demands unrelentless time and effort by all in the eye care fields. In this paper I will submit cases of only simple and compound myopia, which comprise the greatest percentage of my practice.

Most every child diagnosed as having incipient myopia, non-progressive or progressive, simple or compound, and free of ocular pathology is recommended for complete contact lens corrective care-Orthokeratology. Firstly, it is pointed out to the parent that contact lenses prescribed in the usual or regular method of cosmetic fitting will tend to retard the progression of myopia twenty-five to fifty-three per-cent [3]. We also know from Neilson, May and Grant [4] that by prescribing contact lenses, and systematically changing the base curve of the lens as the corneal

curve changes, visual acuity will gradually increase. Furthermore, stability of the cornea develops with less possibility of regression as the young patient approaches maturity in age. Ziff [6] shows a trend of corneal curvature changes that can be anticipated as a result of Orthokeratology procedures. According to Hirsch [5] those of us who work with contact lenses know that corneal flattening is often observed after prolonged wearing of lenses with certain curvatures, the cornea remaining flat for various periods of time. He also says that although obvious difficulties are apparent, the fact that we may be able to change the corneal curvature is nonetheless interesting and a system of myopia prevention could evolve along these lines .Kelly [7] states the best age to arrest myopia must be as soon as it appears. This may be up to age fifteen. He further states that there is enough statistical and factual evidence in both graphs and in tables to say there is *no doubt that contact lenses do have an effect of arrest either temporary or possibly permanent in some cases.* Rengstorff[8] concluded that his own findings are inconsistent with the hypothesis that the cornea returns to its original shape after cessation of contact lens wear. He reports that many subjects have been studied for over fifty days after the removal of contact lenses and there was no evidence at that time to indicate a continuing change (regression) in curvature of the cornea.

I emphasize with every new corrective care case that the procedures are designed to specifically retard or arrest the progression of myopia. Once this is accomplished, usually over a period of one to three years as the case may be, corrective contact lenses are then designed to regain some or all of the deficient visual acuity. This approach is applicable to all cases of *non-pathological* myopia but could possibly be disproved by controlled research. Howover, I am not aware of anything to the contrary in literature to date. Continuing care is necessary over a five year period of time for stabilization to take place, using retainer, low prescription or plano part time contact lenses. Contact lenses are indicated in some cases for night wear (during sleep) when visual acuity is normal through the waking hours.

This seems to be the most effective procedure to maintain corneal curvature changes and normal vision. You can readily see that no guarantees are made with regard to complete permanent correction of vision any more than would be forthcoming in Orthodontia, Orthopedics, surgery or any of the health professions. Patients do not expect guarantees, but only the finest professional care as a result of using the latest research and techniques available.

When prescribing the first pair of lenses for Orthokeratology care, I use P.E.K. (Photo Electronic Keratometry) [14] analysis eliminating keratometric readings as a basis for any contact lens fitting. The PEK approach is a manuscript in itself. It is a phylosophy which allows me to design contact lenses that are most compatible with the cornea. The diagnostic information derived from PEK is most accurate

(96% successful) [14] in determining base curve, optical zone and size relationship over an 8-10 mm. area of the cornea. The relationship of base curve, optical zone and size by regular K readings are trial and error rather than a determined relationhsip. Thus the initial pair of lenses worn by the patient is the first step in corrective contact lens procedure. Since P.E.K. is not widely used I will give the recommended keratometric fitting techniques for all types of Orthokeratology cases of emmetropization.

RECOMMENDED FITTING PROCEDURES IN ORTHOKERATOLOGY FOR CASES OF EMMETROPIZATION

1. Keratometer readings.
2. Peripheral readings.
3. Opthalmoscopy.
4. External examination.
5. Slit lamp.
6. Refraction
7. Pupil size S-M-L.
8. Aperature (Area between lids).
9. Design first pair of lenses (All day comfortable wearing of lenses completely compatible to the cornea must be the criteria for the first pair of contacts designed).

MYOPE

(1) B.C. 8.00 to 8.50 on K
(2) B.C. 7.35 to 8.00, .12D to .50D flatter than K
(3) B.C. 7.35 to 7.00, .50D to 1.00D flatter than K

O.Z. & size:	*RX:*
.1mm larger than regular	Subj.
7.6 O.Z. 9.0 size	+ amt.
per .50 diopter	Flatter|K

HYPEROPE

(1) B.C. 8.00 to 8.50 on K
(2) B.C. 7.35 to 8.00, .12 to .50 steeper than K
(3) B.C. 7.35 to 7.00, .50 to 1.00D steeper than K

O.Z. & size:	*RX:*
.1mm smaller than average 7.6 O.Z., 9.0 size per .50 diopter	Subj. — amt. steeper than K

ASTIGMAT TO 1.00 D

(1) B.C. 8.00 to 8.50 on K
(2) B.C. 7.35 to 8.00, .12D to .50D flatter than the flattest meridian
(3) B.C. 7.35 to 7.00, .50D to 100D flatter than the flattest meridian meridian (use .12).

O.Z. & size:	*RX:*
.1mm smaller than regular 7.6 O.Z. & 9.0 size per .50 diopter	subj. + amt. flatter than K

ASTIGMAT TO 2.00 D

BC	*O.Z. & size:*	*RX:*
use ½ amt cyl steeper than flattest K flatter than steepest K	.1mm smaller than regular 7.6 oz. & 9.0 size per .50 diopter	subj. — amt. steeper than K

ASTIGMAT TO 5.00 D

BC	*O.Z. & size*	*RX*
use ⅔ cyl to 5.00D steeper flattest meridian ⅓ cyl. flatter steepest meridian	.1mm smaller for every ½ diopter steeper	subj. — amt. steeper than K

10. 2nd and subsequent lenses to be prescribed as follows:
NEW LENSES - New keratometric readings combined with compensation for plus acceptance through old lenses together with formula for prescribing the original lenses.
EXAMPLE: Subjective —2.00 BVA K 45.00 sph 7.50 9.0 size, 7.6 O.Z.

ORIGINAL LENSES

B.C.	*Power*	*Size*	*O.Z.*	*Pc*	*CT*
7.58	—1.50	9.0	7.7	11.50/.2 9.00/.4	.009

Check up: K 44.50
7.58 subj. —1.00 BVA

2ND PAIR OF LENSES

B.C.	*Power*	*Size*	*O.Z.*	*Pc*	*CT*
7.67	—.50	9.1	7.8	11.50/.2 9.00/.4	.009

11. After all day wearing do ortho progress analysis every four weeks for a period of three months. The next six months continue ortho analysis every six weeks and subsequently every eight weeks.

12. Continue change of lenses as: The keratometric readings change, when plus acceptance is indicated and/or to create the desired change. No further change of lenses is indicated when any case has the subjective examination of O.U +.75 sph BVA 20/20. (Normal visual skills must be maintained).

13. The last pair of contacts worn are used as all day retainers for corneal stabilization until the eyes have reached maturity.

14. Once visual maturity develops, all day wearing time is reduced one hour at a time every six weeks unless regression takes place.
Under these circumstances wearing time is reduced one hour every twelve weeks.

15. Prescribe plano or plus retainer contact lenses during waking hours for cases not having reached maturity, visually corrected to 20/20 and with subjective finding of +.75.

16. With visual maturity, to maintain stabilization of the cornea night retaining lenses are worn during sleep. They are not worn during the waking hours

as visual acuity remains at 20/20. On the subject of "maturity", I refer to different descriptions and explanations; Gardner, M.D. states: "When growth ceases new cases (of myopia) are rare and major changes in refraction are very exceptional. My experience is that in the twenties the onset of myopia is usually associated with some well marked physical event such as illness, changes in weight, and occasionally pregnancy" [12].

"Maturity" in this paper refers to when growth ceases or that period of time a teenageer enters into adult years as explained by R. Walkingshaw's "Control of Progressive Myopia Through Modification of Diet". He states: "The problem of myopia. This falls into three distinct phases.

1. Juvenile: This group ranges from age 5 to adolescence, but as adolescence, is too variable, 13 has been chosen.
2. Teenage: These have been grouped from 14 to 20 years.
3. Adults: I used to think that all myopia would become stabilized in at latest the upper teenage group, but now I am increasingly aware that the diminution of vision extends into the adult years" [13].

I interpret maturity to be when growth ceases and or the teenager enters adulthood between the ages of 18 and 22. This will vary with each individual case.

The effects from wearing retaining lenses during sleep are as follows:

1. Corneal curvature changes are retained or stabilized in a particular case. When contact lenses are removed the patient has 20/20 vision but some regression would take place if the lenses are kept off on a permanent basis too prematurely.
2. Seven to ten hours of wearing contact lenses during sleep is a sufficient retainer to maintain 20/20 during the day in normal environment with the lenses off.

The following "Progress Analysis" form is now submitted for regular ortho check-ups to determine when a new pair of corrective contact lenses should be prescribed and designed:

ORTHOKERATOLOGY PROGRESS ANALYSIS

Date Contact lens worn hours daily since last checkup.
Patient's statement:

Lenses of date ——— R ——— L ———

Tests with C. L. on: VA R ——— L ——— OU ———

Refr: R ——— Sph Cyl X Max 20/20 R ——— Sph Cyl X BVA

L ——— Sph Cyl X Max 20/20 L ——— Sph Cyl X

Florescein Stipling R yes — no
L yes — no

Abrasion R yes — no
L yes — no

Lag Centered N—T—S—I Lag Centered N—T—S—I

Tests with lenses off: How soon after removal ——— Hrs—Min—Days—Months

Slit lamp exam: Edema R — yes no; L — yes no

Fluorescein on Cornea ———

VA R ——— L ——— OU

Retnos R ——— L ——— OU

Refr: R ——— Sph Cyl X Max 20/20 R ——— Sph Cyl X BVA

L ——— Sph Cyl X Max 20/20 L ——— Sph Cyl X

Spectacle L yes — no OU yes — no

Keratometer: R ——— ; ——— L ——— ; ———

Mires: R Normal — distorted L Normal — rted

VA 15 minutes after CL off R ——— L ——— OU ———

Inspection of CL R surface clear scratched dried mucus

L surface clear scratched dried mucus

Neutralization RC of lens worn L ——— ———

Comments:

The following eight cases were started for Orthokeratology corrective contact lens care two and one-half years ago. They were reported in the Southern Journal of Optometry March 1965 [6]. Only the most recent set of findings will be compared to the original findings previously reported. Intermediate changes of contact lenses that have preceded the last set of findings in each case are not included in this report. It must be understood that at every progress analysis where corneal curvatures flattened. 25 diopters or more, new contact lenses were designed to satisfy the corneal changes. The original eight cases, plus thirty three additional patients accepted for corrective contact lens care are reported in this summary. Findings show the relationship of visual acuity to the existing corneal curvatures and its subsequent changes.

The rationale for orthokeratology has been given a general explanation by Neilson, May and Grant [4]. Pages 4 and 5 contain a more detailed explanation for the rationale used in all types of cases.

The subsequent stabilization and improvement of visual acuity in the following cases is obvious: Diverging light refraction to the retina, improving visual acuity is accomplished by flattening the corneal curvatures. Concerning stabilization Angrist, M.D. states: "It is significant that progressive myopia involves the young. The adult eye does not stretch, i.e., after the collogen fiber has become adequately cross-linked; then it has *stability* or strength, and further stretching does not occur" [9].

In hyperopic cases (which I have not included) a steeper lens steepens the flattest medirian of the cornea, converges light to focus closer to the retina and results in better acuity. For astigmatic cases the principle meridians respond in the following manner: 1. The flattest meridian becomes steeper. 2. The steeper meridian becomes flatter. Both 1 and 2 can take place resulting in less astigmatic abnormality and better visual acuity.

Visual acuity improvement is acheived by the rationale described herein and substantiated by Barnet, M.D. "If contact lenses have any effect on the static refraction of the eye, it would seem to be through one of the following: 1. Changing the corneal curvature. 2. Some effect through the ciliary body (etc.) causing: a. A change in the position of the lens. b. A change in the refraction of the aqueous n. 3. A change in the length of the eye. All of these except the aqueous n can be measured and followed. It is extremely unlikely that enough change in the aqueous n to cause a significant change in refraction could occur. (The word "static" is inserted to eliminate situations in which contact lenses cause more relaxation of accomodation than occurs without them. This might occur in pseudo-myopia, or in high corneal astigmatism.) It is suggested therefore, that the statistical or ex-

EIGHT CASES OF EMMETROPIZATION

Patient Nº 1 –12 years of age, M. R.

7|2|63

Rx in glasses before rafraction for BVA:	Unaided Vision before refraction:	Rx in glasses indicated at refraction for BVA:	Keratometer reading before contact lenses:	Original contact lens used:
R-4.50 50x180 L-5.25 25x135 Wearing for 6 mos.	R 800B L 800B O.U. 800B	R-5.25-50x 10 L-5.75-50x145 BVA 20|20	R 45.50x 3 46.87x 92 L 45.75x180 47.00x 90	R 7.67 (1.50 diopters) L 7.63 (flatter than K)

	Unaided vision after the removal of contacts.	Refraction for BVA after removal of contacts	Keratometer readings after contacts were removed	Contact lenses now worn, G. C.
8|6|65 - Age 14 Wearing lenses 14 hours daily	R 100 L 100B O.U. 100	R-3.50-50x90 L-3.75-50x90 BVA 20|20	R 44.50x 15 45.00x105 L 44.50x180 45.00x 90	R 7.89 L 7.85

SUMMARY OF PATIENT No. 1

Patient number 1 bas been on corrective contact lens eare for past two and one-half years. Corneal curvatures have flattened over 1.00 diopter. Visual acuity shows improvement from 20|800 to 20|100. Refraction indicates a prescription considerably weaker than the original findings. Developmental growth would manifest itself in the form of progressive myopia had corrective contact lenses not been prescribed. Snbjectively the patient sees clearer in her environment when her contacts are removed or before they are inserted in the morning. Corrective procedures are continuing to counteract progressive myopia that would inevitably take place.

Patient Nº 2 - 12 years of age G. R.

8|26|63

Rx in glasses before refraction for BVA	Unaided Vision before refraction:	Rx in glasses indicated at refraction for BVA:	Keratometer reading before contact lenses:	Original contact Lens used:
R-2.00 20|30 L-2.25	R 200B L 200B O.U. 100B	R-2.75 L-3.25 BVA 20|20	R 45.75x180 45.50x L 45.75 sph	R 7.45 (½ diopter) L 7.45 (flatter) (than K)

	Unaided Vision after the removal of contacts:	Refraction for BVA after removal of contacts:	Keratometer readings after contacts were removed:	Contact lenses now worn, B.C:
12|6|65 - Age 14 12-14 hours daily	R 20B L 30B O.U. 20B	R-1.00 L-1.25-.50x90	R 44.00 sph L 44.00 sph	R 7.75 L 7.73

SUMMARY OF PATIENT No. 2

Patient Nº 2 wore glasses for the past three years before corrective contact lenses were prescribed. Her original refraction of 8|26|63 indicated progressive Myopia, substantiating the fact that her glasses bad been increased three times previous to this refraction. After prescribing contact lenses by the specialized technique, the corneal curvature flattened and the contact lenses were redesigned with flatter base curves combined with the appropriate power changes. With fourteen months of corrective contact lens care visual acuity improved from 20|200 to 20|60. For the next twelve months no further change seemed to take place until reevaluation.

PEK keratographs it was found that although the lenses she was wearing in relationship to K readings seemed to be flat, PEK analyais indicated the contact lenses were too steep for her corneas to anticipate additional improvement. New lenses were designed flatter hy using the PEK analysis (7.75 7.73) and in four months the corneas showed further gradual flattening with improved visual acuity to 20|20B. Keratometric mires and PEK rings were not distorted. Slit lamp observations were negative, no edema indicated. The patient's visual acuity of 20|20 is apparent immediately upon the removal of her contact lenses. However the lenses will be worn continuously during the waking hours until the eye reaches maturity. Only then will wearing time be reduced, hourly as long as no regression takes place. I then forsee night retainers during sleep with no contact lenses necessary during waking hours.

Patient Nº 3 - 12 years of age G.R

9|28|63

Rx in glasses before refraction for BVA:	Unaided Vision before refraction:	Rx in glasses indicated at refraction for BVA:	Keratometer reading before contact lenses:	Original contact lens used:
No glasses worn	R-30B -2 L-60B -4 O.U. 30B-2	R-.50- 50x90 L-1.00- 50x100	R 46.00 sph L 46.50 sph	
12|27|63 No glasses	R 60B L 80B O.U. 40B	R-1.00- L-1.50-	R 46.12x165 46.00x 75 L 46.67x180 sph	R 7.42 (½ diopter) L 7.34 (flatter) (than K)

	Unaided Vision after the removal of contacts:	Refraction for BVA after removal of contacts:	Keratometer readings after contacts were removed	Contact lenses now worn, B.C.:
5|21|65 - Age 14 12-16 hours daily	R 20 L 20 O.U. 20	R. .50 L+ .25	R 44.75 sph L 44.75 sph	7.68 7.67
5|26|65 C.L off and not worn for seven (7) days-referred to Ophthalmologist for general visnal checkup and verification.				
	R 20 L 20 O.U. 20	(R+1.00-.25x90 Max 20) (L+ .50-.25x90 + 20) R PL-.25x90 BVA 20|20 L ..50-.25x90	R 44.75x180 45.37x 90 L 45.25x180 45.50x 90	7.68 7.67

SUMMARY OF PATIENT No. 3

Patient Nº 3 is the twin sister of Patient Nº 2. Glasses had never been prescribed as her condition showed gradual incipient to progressive myopia. Corrective contact lenses were prescribed and systematically the base curves were designed flatter as the corneal curvatures flattened and visual acuity improved from 20|40 to 20|20.

VEN CONSECUTIVE DAYS WITH NO REGRESSION OF VISUAL ACUITY. The patient at this time was referred to an Opthalmologist for verification of visual improvement and to substantiate the negative slit lamp findings in observing normal corneal integrity. The contact lenses (7.68 7.67) are still being worn as a "retainer brace" and will not be removed on a reduced wearing schedule until it is certain the eyes have fully matured and there is no chance of regression. The patient, most of the time, sees as clearly with her contact lenses off as she does with them on. Plus +25 is incorporated in her prescription to develop further plns acceptance.

Patient Nº 5 - 15½ years of age . S.H.

5|2|64

Rx in glasses before refraction for BVA:	Unaided Vision before refraction:	Rx in glasses indicated at refraction for BVA:	Keratometer reading before contact lenses:	Original contact lens used:
R -1.50 L -1.50 Wearing for 1 year	R 100B L 100B O.U. 80B	R -2.00 L -1.75	R 43.00x10 43.50x10 L 43.00x10 43.75x90 43.00=7.85= flattetst K reading	R 7.90 L 7.90 O.U. (¼ diopter) (flatter) (than K)

	Unaided vision after the removal of contacts:	Refraction for BVA after removal of contacts:	Keratometer readings after contacts were removed	Contact lenses now worn, B.C.:
10|19|64 - Age. 16 14-15 hours daily	R 20 L 20 O.U. 15	R +.75-.50x90 L Pl	R 42.00x 10 42.25x100 L 42.25x180 43.75x 90	R 8.00 L 8.00
12| 1|65 - Age. 17 14 hours daily	R 40B L 40B O.U. 30B	R -1.00 20|20 L -1.00	R 42.00x 10 43.00x 95 L 42.50x180 43.75x 90	R 8.04 L 8.04

SUMMARY OF PATIENT No. 5

From October 19, 1964, patient Nº 5 has shown regression of 20|20 to 20|40 at the present time. This, of course, is still improved visual acuity from the original progressive myopic condition of 20|80's. This case as in case Nº 4 is obviously going through a growth stage that would under so called normal conditions show decrease of visual acuity as a result of progressive myopia. Refraction for BVA without contact lenses is -1.00D, approximately one-half of the original prescription necessary before contacts were prescribed. Corneal curvatures have gradually flattened and contact lenses redesigned as corneal curvature change so indicated. An opthalmologist verified the negative slit lamp findings and re-affirmed the improved visual acuity.

Patient Nº 6 . 18 years of age E. F.

5|15|64

Rx in glasses before refraction for BVA:	Unaided Vision before refraction:	Rx in glasses indicated at refraction for BVA:	Keratometer reading before contact lenses:	Original contact lens used:
R -1.75 L -1.25-.50x185	R 100B L 40B O.U. 60B	R -2.00 L -1.50-.50x165	7.54 R 44.75x5; 45.75x95 L.44.50x180; 46.00x90 7.58	R 7.71 1 D Flatter L 7.76 Corneal edema

	Unaided vision after the removal of contacts:	Refraction for BVA after removal of contacts:	Keratometer readings after contacts were removed	Contact lenses now worn, B.C.:
9|1|65 . Age 20 12 . 13 hours daily	R 25B L 20 O.U. 20	R x.50 50x90 20|20 L x1.5050x90	R 44.75x180 43.50x 90 L 44.00x180 45.25x 90	7.63 7.59
12|21|65 Lenses off for 48 hours	R 60 L 60 O.U. 30		R 45.25x180 46.00x 90 L 45.00x180 46.00x 90	

SUMMARY OF PATIENT No. 6

One year ago this patient retained 20|20 visual acuity for 91 hours (approximately four daya) after removing his contact lenses. He was examined by an ophthalmologist and by the optometrist who referred him for corrective contact lens care. Both practitioners verified the improved visual acuity and normalcy of the corneal tissue. During the past three months his contact lens wearing schedule has been erratic-three to six hours some days, twelve to fourteen hours other days. This is due to the fact that visual acuity has been clear withotu lenses. For corrective contact lens care to continue it will be necessary for the patient to again wear his lenses consistently, twelve to thirteen hours daily. When his visual findings improve, as occured on September 1, 1965, night retainer lenses during sleep will be prescribed. The patient is now nearing visual maturity.

Patient Nº 7 - 17 years of age M.

9|28|63 Rx in glasses before refraction for BVA:	Unaided Vision before refraction:	Rx in glasses indicated at refraction for BVA:	Keratometer reading before contact lenses:	Original contact lens used:
R +.50-2.00x180 L +.25-1.75x 10	R 60B L 60B O.U. 60B	R +.75-3.00x180 L +.25-2.50x 10	R 42.00x180 8.04 45.75x 90 7.38 L 42.00x180 45.00x 90 7.50	7.71 7.71

	Unaided vision after the removal of contacts:	Refraction for BVA after removal of contacts:	Keratometer readings after contacts were removed	Contact lenses now worn, B.C.:
10|31|64 15 hours daily for 6 months 6-3|4 hours daily for past 6 months	R 25 L 25 O.U. 20	R +.75-1.50x180 20 L Pl -1.50x180 20	R 41.75x155 44.75x 65 L 42.25x 15 44.50x105	7.80 7.80
9|1|65 - Age 19 All day 12½ hours	R 25 L 20 O.U. 20B	R +1.00 .3.00x170 L -.25-1.75x15	R 42.50x175 45.25x 85 L 42.62x 15 45.00x105	Since 2|20|65 7.80 7.80

SUMMARY OF PATIENT No. 7 (The rationale for prescribing corrective lenses here is explained on pages 4 and 5 for astigmats 2.00 to 5.00 diopters)

This case was fitted with B.T. lenses 2.00 D steeper for the right eye and 1.75 D steeper for the left eye. Although the base curves were steeper than the flatter meridian they were still flatter than the steeper meridians. It is interesting to note the reason for improvement in this case of moderate cylinder. The steeper meridians of both eyes became flatter resulting in less astigmatic error and improved visual acnity. *For six months (April* 31 1964 *to October* 31, 1964 *the patient was seeing clearly and comfortable with or without his contact lenses and was wearing them approximately six and* 3|4 *hours daily. Flattened corneal curvatures remained stable and visual acuity didnot regress during this six month period.* Lenses were redesigned to 7.80 B.C. In the past year findings indicated that althongh visual acuity remained R25, L20, O.U. 20, corneal cnrvatures steepened (flattest meridian). The steepest meridians have remained flatter than the original K readings. I will again have the patient wear the lenses of September 28, 1963 (7.71) as best visual improvement and corneal curvature changes and stabilization have resulted from these lenses.

Patient Nº 8 - 18 years of age S.A.

3/7/64

Rx in glasses before refraction for BVA:	Unaided vision before refraction:	Rx in glasses indicated at refraction for BVA:	Keratometer reading before contact lenses:	Original contact lens used:
R-1.00-1.00x100 L-1.50-1.25x	R 200 + 1 L 200 + 2 OU 200 B	R-1.00-1.25x100 L- .75-1.25x 85	R 41.75x175 8.08 42.00x 85 8.04 L 42.00x 55 8.04 42.50x 95 7.94	on K R 8.0887 L 8.04

	Unaided vision after the removal of contacts:	Refraction for BVA after removal of contacts:	Keratometer readings after contacts were removed	Contact lenses now worn, B.C.:
8/15/65 - Age 20	R 60 L 60 O.U. 60		R 42.12x170 42.75x 80 L 42.50x 25 42.75x115	R 8.08 L 8.04

SUMMARY OF PATIENT No. 8

Case Nº 8 has not been consistent for corrective progress analysis. After PEK indicated the need to redesign new contacts flatter than K readings indicated, the procedure was rejected and the patient is still wearing the originally prescribed contact lenses. It can be predicted as in other regularly fitted contact lens cases that there is less possibility permaneut retention of the gains already made.

The eight cases (16) eyes submitted for orthokeratology study have shown to date (2-1|2 years) the following changes in visual acnity in relationship to the corneal curvatures:

Case Nº	*Original Unaided V.A.*	*Present Unaided V.A.*	*Original K Readings*	*Present K Readings*	*K. Changes Flatter or Steeper*
1. M.R.	R 800B	R 100	R 45.50x 3	R 44.50x 15	R 1.00F
	L 800B	L 100B	46.87x 92	45.00x105	1.87F
	O.U. 800B	O.U. 100	L 45.75x180	L 44.50x180	L 1.25F
			47.00x 90	45.00x 90	2.00F
2. G.R.	R 100B	R 20B	R 45.75x180	R 44.00 sph	R 1.75F
	L 100B	L 30B	45.50x 90		1.50F
	O.U. 100B	O.U. 20B	L 45.75 sph	L 44.00 sph	L 1.75F
					1.75F
3. G.R.	R 60B	R 20	R 46.00 sph	R 44.75x180	R 1.25F
	L 80B	L 20	L 46.50 sph	45.37x 90	62F
	O.U. 40B	O.U. 20		L 45.25x180	L 1.25F
				45.50x 90	1.00F
4. R.R.	R 200B	R 200	R 42.62x180	R 42.87 sph	R .12S
	L 200B	L 200	42.87x 90	L 43.62x180	No change
	O.U. 200B	O.U. 200	L 43.00 sph	42.75x 90	L .62S
					.25F
5. S.H.	R 100B	R 40B	R 43.00x 10	R 42.00x 5	R 1.00F
	L 100B	L 40B	43.50x100	43.00x 95	.50F
	O.U. 80B	O.U. 30B	L 43.00x 10	L 42.50x180	L .50F
			43.75x 90	43.75x 90	No change
6. E.F.	R 100B	R 25B	R 44.75x 5	R 44.75x180	R No change
	L 40B	L 20	45.75x 95	45.50x 90	.25F
	O.U. 60B	O.U. 20	L 44.50x180	L 44.00x180	L 50F
			46.00x 90	45.25x 90	75F
7. M.	R 60B	R 25	R 42.00x180	R 42.50x175	R 50S)
	L 60B	L 20	45.75x 90	45.25x 85	.50F)
	O.U. 60B	O.U. 20B	L 42.00x180	L 42.62x 15	L .62S
			45.00x 90	45.00x105	No change
8. S.A.	R 200+1	R 60	R 41.75x175	R 42.12x170	R .62S
	L 200+2	L 60	42.00x 85	42.75x 80	.75S
	O.U. 200B	O.U. 60	L 42.00x 55	L 42.50x 25	L .50S
			42.50x 95	42.75x115	.25S

Included in this study for the past year are an additional thirty-one cases (62 eyes).

9. E.D.	R 200B	200B	R 39.50 sph	40.25 sph	R .75S
Age 18-20	L 200B	200			
	O.U. 200B	200B	39.00 sph	39.62x175	L .62S
				39.75x 85	.75S
10. P.M.	R 200	60B	R 40.50x180	R 40.50x 5	R No change (H)
Age 16	L 200+	60B	41.75x 90	41.25x 95	.50F
	O.U. 200	60B	L 40.50x180	L 40.37x 5	L .12F
			41.50x 90	40.87x 95	.62F

Case N⁹	Original Unaided V.A.	Present Unaided V.A.	Original K Readings	Present K Readings	K. Changes Flatter or Steeper
11. A.S.	R 400B	R 100B	R 42.25 sph	R 40.37x 15	R 1.87F
Age 24-32	L 400B	L 60B	L 41.75x180	41.25x105	1.00F
	O.U. 400B	O.U. 80B	42.50x 90	L 41.25x 15	L .50F
				41.75x105	.75F
12. L.L.	R 80+2	25	R 42.25 sph	R 41.50 sph	R .75F
Age 17-20	L 200B	20	L 42.12 sph	L 41.25x 90	L .87F
	O.U. 80	20B		41.50x180	.62F
13. J.L.	R 200B	20B	R 42.25x180	R 41.00x180	R 1.25F
Age 18-21	L 200B	20B	42.50x 90	42.25x 90	.25F
	O.U. 200B	20B	L 42.25x 15	L 40.75.x 10	L 1.50F
			42.75x105	42.00x100	.75F
14. B.H.	R 200	100	R 42.25 sph	R 42.25x 5	R No change (H)
Age 16-20	L 200+	100B	L 42.75x180	42.00x 90	.25F
	O.U. 200+	100B	42.25x 90	L 42.00 sph	L .75F
					.25F
15. S.K.	100 + 1	20	R 42.50 sph	R 41.25x180	R 1.25F
Age 19	100 + 1	20	L 42.50x180	41.62x 95	.87F
	80	20	42.75x 90	L 41.25x 5	L 1.25F
				41.37x 95	.87F
16. J.H.	R 400B	R 200	R 42.50x180	R 42.00x180	R .50F) .37F
Age 23-27	L 400	L 200+	43.50x 90	43.62x 90	.12S)
	O.U. 200B	O.U. 200+	L 43.00x 10	L 42.00x180	L 1.00F
			43.50x100	43.25x 90	.25F
17. R.D.	R 200B	800	R 42.50x180	R 43.50x180	R 1.00S
Age 18-20	L 200B	800	42.00x 90	42.75x 90	.75S
	O.U. 200	400B	L 42.00 sph	L 42.50x180	L .50S
				42.25x 90	.25S
18. W.F.	R 60 +3	20B	R 42.75x 15	R 43.00x 15	R .25S) 0
Age 18-21	L 100	40B	45.25x105	45.00x105	.25F)
	O.U. 40B	20B	L 42.50x175	L 42.75x180	L .25S
			46.00x 85	46.00x 75	No change (V)
19. I.M.	R 200B	80	R 42.75x180	R 42.00x180	R .75F
Age 25	L 200B	80+	43.75x 90	43.25x 90	.50F
	O.U. 200	80+1	L 42.75x 5	L 42.00x 10	L .75F
			43.75x 95	42.75x100	1.00F
20. N.L.	R 800B	R 80B	R 43.00x180	R 41.50x165	R 1.50F
Age 22-24	L 800	L 20B	44.25x 90	42.00x 75	2.25F
	O.U 800	O.U. 20B	L 43.00x180	L 41.62x180	L 1.37F
			44.25x 90	42.25x 90	2.00F
21. E.P.	R 800B	400B	R 44.00x180	R 43.25x170	R .75F
Age 13-15	L 800B	100+3	44.75x 90	44.50x 80	.25F
	O.U. 800B	100+2	L 43.25x180	L 41.87x160	L 1.37F
			44.75x 90	42.75x 70	2.00F

Case Nº	Original Unaided V.A.	Present Unaided V.A.	Original K Readings	Present K Readings	K. Changes Flatter or Steeper
22. M.H. Age 13	R 200 L 200B O.U. 100B	R 20 L 20 O.U. 20	R 43.50 sph L 44.25x180 44.50x 90	R 42.50x180 42.75x 90 L 42.75x175 43.00x 90	R 1.00F .75F L 1.50F 1.50F
23. T.F. Age 13	R 100 L 80B O.U. 60B	R 30 L 40 O.U. 20	R 43.75x 35 44.00x125 L 44.25x170 44.50x 80	R 43.00x180 42.50x 90 L 43.00 sph	R .75F 1.50F L 1.25F 1.50F
24. R.C. Age 19-26	R 200 L 200 O.U. 200	60 80 60	R 43.75x180 44.00x 90 L 43.75x180 44.00x 90	R 43.00x 30 43.50x120 L 42.75x180 43.50x 90	R .75F .50F L 1.00F .50F
25. S.N. Age 17	R 800R L 800B O.U. 800B	100B 100B 100B	R 43.87x180 44.62x 90 L 43.87x 10 44.87x100	R 42.87x180 43.50x 90 L 42.75x 15 43.75x105	R 1.00F 1.12F L 1.12F 1.12F
26. G.R. Age 7-8	R 200B L 200B O.U. 200B	200R 200R 200B	R 43.50x 25 46.50x160 L 43.50x160 46.50x 70	R 44.37x 25 46.25x115 L 44.37x170 46.00x 80	R .87S) .62S .25F) L .87S) .37S .50F)
27. J.A. Age 14-19	R 800 L 800 O.U. 800	R 200 L 100 O.U. 60B	R 44.00x175 44.25x 85 L 44.00x 10 44.50x100	R 42.62x175 45.00x 85 L 42.50x 10 45.00x100	R 1.37F) .62F .75S L 1.50F) 100F .50S)
28. F.M. Age 28	R 400B L 400B O.U. 200B	R 100 L 100 O.U. 80+3	R 44.50x180 44.87x 90 L 44.00x 20 45.12x105	R 44.25x175 44.75x 85 L 44.50 sph	R .25F .12F L .50S) .12F .62F)
29. A.W. Age	R 400B L 400B O.U. 400B	800 400 400+2	R 44.50x180 46.25x 90 L 44.75x180 46.25x 90	R 44.50x180 44.75x 90 L 45.00x180 46.00x 90	R No change (H) 1.50F L .25S) .25F)

(PEK indicated steeper than K fitting; 1st Lenses for R were on K for L were 1|2 D steeper than K)

30. R.D.	R 200B L 200+ O.U. 200+2	200 200+2 200+2	R 44.72x180 45.00x 90 L 45.00x 20 45.12x110	R 43.62x 30 44.50x120 L 44.50 sph	R 1.12F .50F L .50F .62F
31. R.N. Age 19	R 40B L 60B O.U. 30B	20 60 20	R 44.75 sph 44.62x 20 L 45.25x110	R 44.00x180 44.72x 90 L 44.75x180 45.25x 90	R .75F No change (V) L .50F No change (V)

Case No	Original Unaided V.A.	Present Unaided V.A.	Original K Readings	Present K Readings	K. Changes Flatter or Steeper
32. B.L. Age 15-17	R 200B L 400B O.U. 200B	200B 400B 200B	R 44.75x 10 44.25x100 L 44.25x180 44.75x 90	R 45.00x165 44.37x 75 L 44.75x180 44.87x 90	R .25S .12S L .50S .12S
33. A.K. Age 14	R 800B L 800B O.U. 800B	R 200 L 200+1 O.U. 100+1	R 45.00x 5 45.75x 95 L 45.00x180 45.75x 90	R 44.00x180 44.25x 90 L 44.25x 15 44.75x105	R 1.00F 1.50F L .75F 1.00F
34. K.H. Age 15-20	R 800B L 800B O.U. 800B	800 800 400	R 45.37x180 45.62x 90 L 45.37x180 46.00x 90	R 44.50x180 45.12x 90 L 45.00x180 45.50x 90	R .87F .50F L .37F .50F
35. C.B. Age 10	R 800 L 800 O.U. 400B	R 800 L 800 O.U. 400	R 45.37x165 45.87x 75 L 45.75x 35 46.12x125	R 45.25x175 46.00x 85 L 45.50x 25 46.75x115	R .12F) 0 .12S) L .25F) .62S) .37S
36. L.G. Age 15-18	R 200B L 200 O.U. 200	R 100 L 100 O.U. 100	R 45.50x180 46.25x 90 L 45.50x180 46.75x 90	R 44.37x175 45.25x 85 L 44.50x180 45.50x 90	R 1.12F 1.00F L 1.00F 1.25F
37. C.S. Age 18	R 200 L 200B O.U. 200	R 200+1 L 200+1 O.U. 200+1	R 46.00 sph L 46.75x 5 45.50x 95	R 46.00 sph 46.00 sph L 46.75x180	R No change L No change .75S
38. M.K. Age 15	R 200 L 100B.1 O.U. 100	R 100B (Not a full day wearer) L 80B (Lenses off 1 week - has	R 46.37x180 44.50x 90 L 46.75x180 44.75x 90	R 46.75x180 45.00x 90 L 47.00x175 45.00x 85 cold)	R .37S .50S L .25S .25S
39. P.C. Age 13	R 80B L 200 O.U. 80B	30 200 30B	R 47.00x170 48.00x 80 L 47.25x 30 48.00x120	R 46.00x 5 47.00x 95 L 46.75x 15 47.50x105	R 1.00F 1.00F L .50F .50F
40. P.P. Age 11	R 200B L 200B O.U. 200	R 200B L 200B O.U. 200B	R 47.74x 5 48.62x 95 L 47.62x 5 48.87x 95	R 46.62x 5 48.25x 95 L 47.00x180 48.75x 90	R 1.12F .37F L .62F .12F
41. R.A. Age 16	R 100B L 80B O.U. 80B	R 60B L 30+ O.U. 30	R 44.00x180 44.75x 90 L 44.00x 5 44.75x 95	R 43.25x170 44.00x 80 L 43.25x 5 44.25x 95	R .75F .75F L .75F .50F

perimental group be measured and followed for: 1. Amount of myopia. 2. Corneal curvature. 3. Anterior chamber depth. 4. Length of eye" [10].

According to Monroe Hirsch "The cornea does seem more amenable to alteration. Thus even though a given cornea would in the normal state have a certain curvature, we may still be able to alter it somewhat and still retain its health. For example, it is observed that contact lenses can and do flatten the cornea. The problem here for research will be to determine how much the cornea may be modified with safety, how permanent the result will be and the ages at which therapy might best begin" [11].

SUMMARY

Concerning interpretation of cases 1 through 41 the visual data has been analyzed as much as is possible at this time. If improvement in visual acuity did not take place (4%), axial growth of the eyeball was excessive and, or crystalline lens changes were also a factor. I don't know which took place; only the clinical information, corneal curvature changes in relationship to visual acuity, are presented here.

The desired changes for corrective care procedures are for a flatter lense to create a flatter corneal curvature, and a steep lnes to create a steeper corneal curvature. No attempt has been madc to analyze the reasons for the small percentage (4%) that did not respond to treatment. In a subsequent paper to this interim report follow-up findings will be related to the rationale described on pages 4 and 5.

The chart shows original eight cases (16 eyes) under Orthokeratology corrective care for the past two and one-half years in addition to the thirty three cases (66 eyes) reported for the first time in this paper (totaling 82 eyes). Corneal curvature changes are shown in relationship to visual acuity.

Present K readings Flatter (horizontal & vertical readings combined)	*Improved visual acuity*	*No change visual acuity*	*Decreased visual acuity*
59	50	8	1
Present K readings steeper			
18	6	10	2
Present K readings No change (horizontal & vertical readings combined)			
5	2	3	
Total 82	58	21	3 Totals

The flat to steep corneal curvature ranges are shown here in relationship to visual acuity changes.

		Corneal curvatures	
Original K readings	*No. of eyes*	*Flattened*	*Steepened*
39.00D to 42.00D	10	5	5
42.35D to 46.00D	63	55	8
46.25D to 48.00D	6	5	1
TOTAL	79	65	14

The above 79 eyes (96.4%) showed either vissual acuity improvement (83%) or no change in acuity (13.4%). In cases of incipient or progressive myopia no change in acuity is considered an improvement. The vision of three patients improved from legally blind (20/200) to normal 20/20. Three eyes (4%) with the flattest K readings of 42.00D, 42,00D and 44.50D decreased in visual acuity. The K readings steepened in the two former and flattened in the latter.

In the 39.00D to 42.00D range, 50% of the corneal curvatures flattened with visual acuity improvement. 50% of the corneal curvatures steepened with no change in visual acuity.

Of the 42.25D to 46.00D K range, 87% of the corneal curvatures flattened with visual acuity improvement. 13% of the corneal curvatures steepened no change of visual acuity.

In the 46.25D to 48.00D K range, 83% of the corneal curvatures flattened with visual acuity improvement, 13% of the corneal curvatures steepened with no change of visual acuity.

CONCLUSIONS:

Seventy nine of the eighty two eyes (96%) discussed in this report after a two and one-half year study responded with improved visual acuity or no change in acuity, as a result of Orthokeratology procedures. Corneal curvatures as flat as 40.50D and steep as 47.75D showed the above visual acuity improvement. The eyes indicating greatest improvement (1.00D or more) in relationship to the corneal curvature changes had corneal curvatures of 42.25, 42.50, 43.00, 43.50, 43.75, 43.87, 44.25, 44.75, 45.00, 45.50, 47.00 and 47.75D.

Only three eyes (4%) of all those included in this report showed less visual acuity as a result of emmetropization procedures. Case Nº 5 shows evidence that corneal curvatures and visual acuity will regress if contact lenses are removed permanently before the eyes reach maturity. This also occurs if lenses are worn

on a limited basis during the waking hours as is shown in case Nº 6. This leads me to believe that contact lens wearing time can be reduced only an a systematic hourly basis over a period of months. Furthermore, a large percentage of cases reported indicate clearest vision is after removing the lenses. This tends to support the hypothesis that night retainer lenses during sleep be the most effective means of retaining normal visual acuity during waking hours - the results of which are to be included in the next phase of muy five year study.

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