Results of aphakia correction by lamellar refractive keratoplasty*

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INTRODUCTION

The cornea is responsible for approximately two-thirds of the total refractive power of the eye. Therefore, it is possible to suppose that induced changes in this tissue may be sufficient to correct the majority of the ametropias found in clinical practice. The corneal refractive power depends upon constant and variable factors. The constant factors are the indices of refraction of the air, of the cornea and of the aqueous humor. The variable factors are the radius of anterior and posterior corneal surfaces and the corneal thickness.

The refractive power of a curved surface situated between media of different refractive indices is given by the formula: $D = n' - n \div r \times 1000$, where D is the dioptric power, n' and n the indices of refraction of the second and first medium respectively and r the radius of curvature in millimeters. Using the mean values preconized by Gullstrand for the constant and variable factors and applying this formula, the refractive power at the anterior cornea surface is 48.83 diopters, at the posterior corneal surface is -5.88 diopters and the third factor, the corneal thickness, is only 0.10 diopters. The resulting dioptric power of the cornea, given by the addition of these three factors, is 43.05. In order to modify the refractive power of the eye, it is evident that it can be accomplished most easily at the anterior corneal surface, since it is the variable factor of greatest magnitute.

The surgical modification of the anterior corneal curvature, aiming at the correction of refractive errors, was pioneered by José Ignacio Barraquer. In 1949 he introduced the term "refractive keratoplasty" for those corneal surgeries that alter the refraction power of the eye. In 1958 he developed the manual cryolathe. In 1963 he introduced the electric micro keratotome. In this same year he presented the first clinical results of keratophakia and the following year of keratomileusis. It is claimed that keratomileusis was the first surgical procedure in which a part of an organ was separated from the human body in order to modify its function, in this case refraction, and then replaced in its original location. Also, for the first time in surgery, an electronic computer was used to tell the surgeon the amount of surgical action necessary to obtain the required therapeutic results. Thus, in the lamelar refractive keratoplasty, the anterior corneal curvature is modified by a controlled alteration of its thickness. The posterior curvature remains unchanged. This technique consists of KERATOPHAKIA (KP) and KERATOMILEUSIS (KM). (From Greek: keratos = cornea; phakos = lens; smileusis = to carve). KM most often is a lamellar refractive autokeratoplasty, whereas KP is always a lamellar refractive homokeratoplasty.

Myopia can be surgically corrected by the MYOPIC KERATOMILEUSIS (MKM), which aims at the increase of the radius of the anterior corneal curvature by flattening the anterior corneal surface, thus reducing its vertex power. A cap of predetermined thickness is excised accurately from the patient's anterior cornea with the high-speed electric micro keratotome. The resected disc is frozen, to make it hard, and its stromal side is carved centrally with the cryolathe. The carved corneal cap, with its reduced dioptric power, is thawed and sutured to the recipient lamellar bed, resulting in a flattened and thinner corneal correcting a corresponding amount of axial myopia.

Hypermetropia can be surgically corrected by KP or by HYPERMETROPIC KERATOMILEUSIS (HKM). In each procedure the radius of the anterior cornea is decreased, correspondingly steepening the anterior corneal curvature to increase the dioptric power of the cornea. KP and HKM can be used to correct both phakic and aphakic hypermetropia. In HKM the patient's resected disc is frozen and has its stromal side carved peripherally. When healed to the posterior corneal lamella, induces the increase curvature of the anterior central surface re-

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quired for the correction. In KP, the donor disc is also frozen and carved into a homolenticule consisting only of stroma of equal power to the refractive error to be corrected. A disc of the patient's corneal is then removed with the micro-keratotome and is replaced with the additional homolenticule accurately centered between it and its original bed, i.e., interlamellarly. The result of either procedure is a controlled steepening of the anterior curvature of the cornea, thus increasing its vertex power and correcting a corresponding amount of hypermetropia.

The preoperative patient data include the patient's corneal thickness, dioptric correction at corneal vertex and initial anterior radius of curvature of the cornea. The refraction of the cataractous eye can be obtained by applying the Littmann's formula, which uses the mean anterior radius of the cornea and the axial length (A scan) of the eye. The intraoperative data comprise the thickness of the patient's anterior lamellar cap, the same measurement in the frozen state, the thickness of the donor's anterior lamellar cap, thickness of the frozen donor disc, thickness of the donor's posterior layer. The preoperative and intraoperative data are entered into the programmable computer from which the cryolathe settings are determined, which are basically the following: the cutting radius, the displacement of the cutting tool of the cryolathe to limit the depth of the resection and the angle of this tool in relation to the axis of rotation of the cryolathe to limit the optical zone.

The presentation of lamellar refractive keratoplasty as a possible means to correct aphakia's hypermetropy with special attention to the postoperative uncorrected and corrected VISUAL ACUITY (VA) consisted the chief goal of the present research.

MATERIAL AND METHOD

The records of cataract patients who underwent KP during the period of 1977 through 1981 and HKM in 1980 were carefully reviewed. The 1980 HKM cases were selected for the present study because they would represent a sufficient data number, recent and with a reasonable follow-up period. With regard to KP, the number of surgeries in this five-year period was much inferior in comparison with the previous years' ones, and with the HKM cases as well. (The results of the past years are well-documented in Barraquer's textbook [1].) This fact is basically due to a decrease in eye donations in the last years. Up to the present time-August 1982 — only one KP case has been operated on by J. I. Barraquer in this year [2].

In 1977-1981 period there were 14 KP cases (in six senile, four traumatic and four congenital cataracts). There were 79 HKM cases in 1980 (in 70 senile, five traumatic and four congenital cataracts). Only the senile cataract patients were included in the present study. Each patient was operated on by the same surgeon (J. I. Barraquer) at "Instituto Barraquer de America". All the patients were subjected to intracapsular cataract extraction combined with the refractive surgery at the same time, with the exception of case 5 in the KP group and case 11 in the HKM group. The latest refraction and its follow-up period were recorded. The shortest acceptable follow-up period was three months. On this account eight patients who had been subjected to intracapsular extraction and HKM were excluded from this study, since they had just one-month follow-up. Eleven patients of the HKM group had postoperative uncorrected visual acuity of fingercounting. In order to calculate the average and the standard deviation, these patients were considered to have an uncorrected visual acuity of 0.01.

TABLE 1

Characteristics of the keratophakia and hypermetropic keratomileusis groups

Group	Period of time	Number of cases	Age (years)			Sex		Operated eye		Follow-up period (months)		
			Maximum	Mean	Minimum	Male	Female	Right	Left	Maximum	Mean	Minimum
KP	1977-81	6	74	59.7	43	1	5	4	2	37	17.3	4
HKM	1980	62	81	61.6	42	33	29	33	29	30	13.9	3

The following table shows the characteristics of each studied group.

The patients who showed improvement in the corrected visual acuity after surgery were classified into three classes as follows, according to the amount of correction needed to reach the best visual acuity:

0.00 —— 3.00 diopters = good optical correction

3.25 —— 6.00 diopters = moderate optical correction

over 6.00 diopters = discrete optical correction

RESULTS

KP Group

The mean uncorrected postoperative VA was 0.22 with a standard deviation of 0.11.

The mean corrected postoperative VA was 0.57 with a standard deviation of 0.10.

The best corrected VA obtained was 0 67 (cases 4 and 6).

The mean follow-up was 17.3 months.

Vision improved in all patients except case 5 (83.3%). This was the only case in the group which did not have the intracapsular extraction and the KP at the same time. Actually, this patient had been subjected to a combined HKM + intracapsular extraction 41 days prior to the KP procedure. The latter was strongly recommended on account of the serious problems which happened with the lenticule (necrosis).

There were two patients (33.3%) with 0.67 corrected VA and three patients (50.0%) with a corrected VA of 0.60 to 0.50.

The improved acses were classified as: Good optical correction: four patients (66.7%), cases 2 3, 4, 6. Discrete optical correction: one patient (16 7%) case 1. However, with contact lens in the VA reached 0.80.

See Table 2 and Graph 1.

HKM Group

The mean uncorrected postoperative VA was 0.19 with a standard deviation of 0.16.

The mean corrected postoperative VA was 0.56 with a standard deviation of 0.20.

The best corrected VA was 0.90 (case 17).

The mean follow-up was 13.9 months.

TABLE 2
Results of keratophakia in aphakia (1977-1981)

Case	Record number	Patient	Age (years)	Sex	Eye	Preoperative visual acuity	Postoperative results			
							Uncorrected visual acuity	Visual acuity	Refraction	Follow-up (months)
1	118575	AGB	57	F	R	FC	0.10	0.50	+ 9.25 — 2.25 x 120°	37
2	124674	RCP	70	F	L	FC	0.20	0.60	+ 2.50 — 2.00 x 180°	32
3	125028	IUS	43	F	R	FC	0.10	0.60	+ 2.50 — 2.50 x 180°	5
4	110597	CH	67	F	R	0.05	0.40	0.67	+ 2.50 — 2.00 x 120°	17
5	137914	HKF	74	F	R	0.40	0.29	0.40	— 1.00	9
6	224225	RO	57	M	L	0 33	0.25	0.67	+ 2.00 — 1.50 x 5°	4

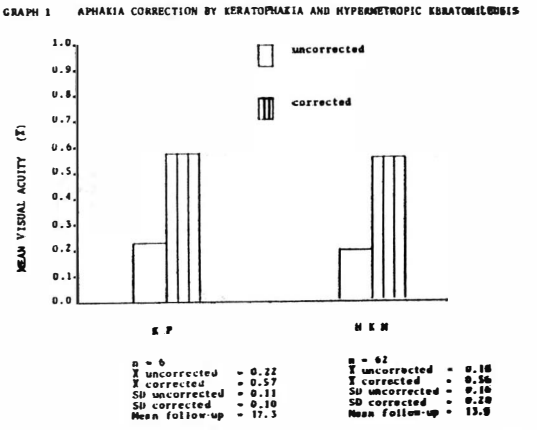
FC = Finger counting

Vision improved in 50 patients (80.6%), decreased in three patients (4.8%), cases 5, 42, 47 —, and remained the same in nine patients (14.5%), cases 11, 13, 32, 39, 44, 45, 49, 50, 57. Case 11 was the only one in this group that did not have the combined procedure (cataract extraction VII/11/79, HKM II/8/80); Case 13 probably had a retinal vascular disease; Case 32 the optical zone was small and decentralized; case 49 had a macular degeneration. No explanation was found in the records for the underlined cases. However, the VA improved in cases 42, 47 (0.50 and 0.67 respectively) and cases 50, 57 (0.80 both) with contact lenses in.

There were 28 patients (45.2%) with a corrected VA equal or superior to 0.67, 26 patients (41.9%) raging from 0.33 to 0.60 and eight patients (12.9%) equal or inferior to 0.32.

The improved cases were classified as: Good optical correction: 15 patients (30.0%). Cases 3, 9, 17, 20, 28, 33, 35, 38, 40, 41, 43, 53, 54, 55, 59. Moderate optical correction: 25 patients (50.0%). Cases 1, 4. 6, 7 8, 10, 16, 18, 19, 22, 25, 26, 27, 29, 30, 34, 36, 37, 46, 48, 51, 52, 56, 58, 62. Discrete optical correction: ten patients (20.0%). Cases 2 12, 14, 15, 21, 23, 24, 31, 60. 61. Case 15 the carving of the disc was partial, and since the surgery had not been completed, a second HKM was recommended. Case 24 had a decentralized optical zone. No obvious reason was found in the records for the underlined cases. Nevertheless, cases 2,60 and 61 had their VA improved to 1.0, 0.8 and 0.6 respectively, with contact lens in.

See Table 3 and Graph 1.



Graph 1 — Aphakia correction by keratophakia and hypermetropic keratomileusis

TABLE 3
Results of hypermetropic keratomileusis in aphakia (1980)

Case	Record number	Patient	Age (years)	Sex	Eye	Preoperative visual acuity	Postoperative results			
							Uncorrected visual acuity	Visual acuity	Refraction	Follow-up (months)
1	282118	BCC	72	M	L	FC	0.25	0.60	+ 3.50 — 1.50 x 90°	10
2	126474	JFN	72	F	R	0.20	FC	0.50	+ 9.00	23
3	282369	ERS	42	M	L	LPJ	0.60	0.67	— 1.00 x 80°	4
4	282439	QVS	43	M	R	0.33	0.20	0.67	+ 5.50 — 2.00 x 75°	28
5	282439	QVS	43	M	L	0.67	0.20	0.40	+ 3.50	25
6	99996	JCB	60	F	L	FC	0.20	0.80	+ 4.50 — 1.25 x 100°	23
7	133077	ASM	69	F	R	0.10	0.15	0.80	+ 5.25 — 1.25 x 30°	4
8	282266	RVL	57	M	L	0.50	0.05	0.80	+ 4.00 — 1.00 x 70°	30
9	133114	SWC	64	F	R	LPJ	0.40	0.67	— 1.75 x 50°	9
10	110597	CH	67	F	L	0.10	0.20	0.80	+ 4.50	16
11	274058	SCGA	74	M	R	0.40	0.15	0.40	+ 9.25 — 3.00 x 70°	3
12	282534	PIJAS	48	M	R	0.15	FC	0.67	+ 9.00 — 2.00 x 170°	4
13	282302	ARR	72	M	L	0.10	0.08	0.15	+ 6.50 — 3.50 x 95°	29
14	274383	MNB	60	M	R	0.05	FC	0.80	+ 8.00 — 2.00 x 50°	4
15	133287	MCB	63	F	R	LPJ	FC	0.60	+13.00 — 2.50 x 165°	3
16	282605	EFA	69	M	R	FC	0.15	0.60	+ 4.00 — 1.50 x 70°	3
17	133461	RRR	61	F	R	0.10	0.80	0.90	+ 1.00	29
18	133461	RRR	61	F	L	0.45	0.33	0.80	+ 4.00 — 2.00 x 135°	29
19	281739	SD	47	M	R	0.10	0.22	0.80	+ 5.00 — 0.50 x 160°	6
20	99739	MAM	46	F	R	HM	0.15	0.40	+ 2.25 — 1.50 x 105°	29
21	271452	GZO	74	M	L	FC	FC	0.33	+ 7.75 — 1.00 x 10°	15
22	282744	APG	81	M	L	FC	0.10	0.67	+ 4.50 — 1.50 x 85°	4
23	134060	ZGK	67	F	L	FC	FC	0.80	+ 7.00 — 2.50 x 140°	27
24	269181	SY	48	M	L	0.67	FC	0.80	+ 6.75 — 2.00 x 165°	20
25	283917	YNT	46	M	R	0.50	0.29	0.80	+ 6.00 — 2.50 x 60°	22
26	277704	BVR	72	M	L	0.40	0.10	0.67	+ 4.75 — 1.00 x 95°	14
27	251264	AAO	66	M	L	0.25	0.30	0.50	+ 3.50 — 2.00 x 120°	24
28	133722	MTCP	60	F	R	FC	0.25	0.45	+ 1.00 — 4.00 x 25°	12
29	105319	CPG	49	F	R	0.15	0.25	0.62	+ 4.50 — 2.50 x 170°	13
30	271696	EGM	66	M	L	0.50	0.10	0.80	+ 3.25 — 1.50 x 165°	7
31	134900	MAL	48	F	R	0.10	FC	0.67	+ 6.50 — 2.25 x 165°	19
32	134900	MAL	48	F	L	0.33	FC	0.40	+ 5.50 — 2.50 x 120°	19
33	284252	CACV	57	M	R	0.15	0.50	0.67	+ 1.50 — 2.50 x 5°	10
34	134927	HEJ	48	F	R	0.33	0.10	0.67	+ 5.00 — 0.50 x 165°	18
35	109579	MZT	71	F	L	HM	0.33	0.40	+ 3.00 — 1.75 x 85°	15
36	134933	HQM	53	F	R	FC	0.20	0.40	+ 3.50 — 2.75 x 70°	13
37	135131	ICB	81	F	L	0.05	0.10	0.29	+ 3.50 — 0.50 x 180°	11
38	134650	HHF	75	F	R	HM	0.10	0.25	+ 1.25 — 4.00 x 55°	21
39	276370	JMGB	61	M	L	0.40	0.20	0.40	+ 3.25 — 2.25 x 25°	5
40	276370	JMGB	61	M	R	0.40	0.45	0.80	+ 1.25 — 0.50 x 180°	4
41	283726	GFB	75	M	R	FC	0.25	0.67	— 1.25 — 1.00 x 90°	12
42	133038	ALG	65	F	R	0.33	0.10	0.15	— 2.00 — 1.50 x 135°	20
43	136171	MZF	68	F	L	0.33	0.50	0.62	+ 0.50 — 2.50 x 25°	4
44	77652	IGA	60	F	L	0.40	0.40	0.40	— 1.00 x 150°	20
45	129828	IRA	69	F	L	0.45	0.20	0.50	— 1.00 — 1.00 x 180°	14
46	285612	EPV	70	M	R	FC	FC	0.40	+ 4.50 — 1.50 x 90°	21
47	272420	ECP	69	M	R	0.40	0.10	0.27	+ 6.00 — 1.00 x 45°	12
48	134176	RUC	66	F	L	0.10	0.10	0.25	+ 5.00	13
49	284312	LM	78	M	L	0.15	FC	0.15	+12.25 — 2.25 x 90°	7
50	136641	MCC	69	F	R	0.30	0.10	0.33	— 3.25 — 1.25 x 85°	5
51	285973	ACR	50	M	R	FC	0.08	0.40	— 3.50 — 4.00 x 10°	4
52	281674	JSF	58	M	R	0.20	0.07	0.40	— 4.00 — 2.00 x 135°	4
53	13458	FAG	60	F	L	0.50	0.15	0.80	— 1.50 x 90°	21
54	286105	RUJ	55	M	R	0.10	0.33	0.50	+ 0.75 — 1.75 x 85°	21
55	137047	LLA	50	F	R	LPJ	0.33	0.50	+ 0.50 — 1.50 x 60°	7
56	101436	LSR	70	F	L	FC	0.25	0.67	+ 4.00 — 6.00 x 65°	13
57	271483	VMGR	73	M	L	0.50	0.40	0.50	— 1.00 x 30°	10
58	136501	AGQ	58	F	R	0.40	0.10	0.67	— 4.00	10
59	286426	FJC	64	M	L	0.05	0.10	0.25	+ 1.00 — 2.00 x 70°	19
60	286516	ALC	55	M	R	0.05	0.10	0.67	+10.00 — 4.00 x 160°	3
61	286516	ALC	55	M	L	FC	0.10	0.33	+10.25 — 2.25 x 110°	3
62	286492	VMG	58	M	R	FC	0.15	0.80	+ 4.00	15

LPJ = Light projection
FC = finger counting
HM = hand motions

DISCUSSION

Lamellar refractive keratoplasty is a relatively-new surgical procedure, carried out on a healthy cornea, to correct ametropias by modifying the radius of the center of the center of the anterior surface of the cornea through the modification of the corneal thickness. The cornea is the major refractive element of the eye, as well as the most

accessible for the modification of its refractive power. Small modifications in its anterior curvature produce significant refractive changes, making possible high degrees of correction. However, there are limitations on the amount of modification a cornea can undergo. Estimated limits are 5.82 mm for steepening and 10.06 mm for flattening. Steeper radii distort the image and demand an excessively small optical zone. Thus, the possibilities of correction depend on the value of the initial radius of the anterior surface of the cornea [3]. As pointed out by Ainslie and Mathalone [4], it is important initially to reserve any new procedure for cases where other more conventional means of treatment are not suitable. For the time being, indication must therefore remain anisometropia with symptons where more conventional methods are either impracticable or where they have failed to bring satisfactory relief. Unilateral aphakia in young children represents an excellent indication.

Several surgical complications have been related: Barraquer[3] refers irregular keratectomy, openings of the anterior chamber, air and CO2 under the lenticule, central and peripheral epithelial downgrowths, severe epithelitis, partial necrosis in HKM cases for aphakia. Ainslie and Mathalone[4] related epithelial ingrowth of the interface with the resultant loosening and lifting of the disc, interface irregularity and foreign bodies at the interface in KM cases. Friedlander et alii[5] have reported perforation in the anterior chamber in one case of KP, dislocation of the lenticule, late epithelial defects, dust particles and epithelial rests lodged in the interface in HKM cases. Swinger and Barraquer[6] mention carving irregularity outside the lenticular optical zone, peripheral epithelial buds and one case of dellen in HKM cases. Troutman et alii[7] encountered an irregular cut adjacent to the pupillary zone, wound dehiscence with epithelialization in a KP case. The present research revealed a case of necrosis of the lenticule (case 5 of KP group) after a HKM associated to cataract extraction 41 days prior to the KP surgery, a case in which the carving of the disc was incompleted (HKM group case 15) and a decentralized optical zone in cases 24 and 32 of HKM group.

Five patients of the HKM group had both eyes operated upon: Cases 17-18; 31-32; 60-61; 4-5; 39 40. The first three patients had both operations (cataract extraction + HKM) in each eye at the same time. This reveals a common proceeding at Barraquer's Clinic in Bogota, Colombia, that is bilateral surgery at same time. According to Barraquer[2] he has never had a case of infection or expulsive hemorrhage in his bilateral surgeries.

The mean uncorrected VA was discretely superior in KP group, whereas the mean corrected VA did not significantly differ between the two groups. Obviously, it must be taken into account the difference between these two groups, as far as the number of subjects is concerned, making it impossible to draw definitive conclusions by comparing them.

Evidently the mean follow-up was longer in KP group.

The early postoperative negative refraction found, for instance, in cases 50, 51 and 52 of the HKM group, usually tend to disappear as time goes by[2]. See Table 3.

There was a patient who had a KP in her right eye (case 4) and a HKM in her left eye (case 10) one month apart. As expected, the former procedure corrected more, i.e., gave a better uncorrected VA, although, the latter provided a superior corrected vision.

According to Barraquer[2], better results been achieved in the last two years, by purposely undercorrecting these cases. The shortest final radius in HKM should be no less than 5.85, in general around 6.1. It ought not to attempt to correct a vertex power over + 11.00 diopters. The reason why better results have been obtained by such a proceeding resides in the fact that fewer epithelial problems as well as a broader optical zone are obtained with a not too steep anterior corneal curvature.

The eyes with a longer axial length are expected to have a better outcome.

Until February 1982 KM and KP were performed using the manual cryolathe and a spherical base (delrin base: plastic disc that carries the corneal disc). From this date on, J. I. Barraquer introduced the computerized cryolathe and the parabolic base and since then better results have been achieved. He provided the author with his latest results of six senile cataract patients subjected to intracapsular extraction and HKM using this new method. See Table 4.

The mean VA is the following	Uncorrected	Correted
One-month follow-up	0.19	**0.60**
Three-month follow-up	0.18	**0.72**

A tendency to undercorrect these patients is evident; see the final radius in Table 4. The shortest final radius was 5.90 and the mean of these six cases was 6.37. Also, the one-month corrected VA proved to be good despite the short postoperative period of time. The three-month corrected VA improved 16 percent in relation to the 1980 HKM result.

TABLE 4
Results of hypermetropic keratomileusis in aphakia (1982)

Case	Record number	Initial radius	Visual acuity				Final radius
			One-month follow-up		Three-month follow-up		
			Uncorrected	Corrected	Uncorrected	Corrected	
1	291536	7.25	0.25	1.00	0.10	1.00	6.00
2	282266	7.65	0.33	0.62	0.33	0.67	6.20
3	290743	7.70	0.25	0.50	0.29	0.67	6.56
4	118176	7.70	0.20	0.50	0.10	1.00	6.75
5	143176	7.30	0.02	0.50	0.15	0.50	5.90
6	291616	8.00	0.08	0.45	0.08	0.50	6.82

It is claimed that the parabolic base increases the optical zone of the lenticule [2]. It must also be taken into consideration that the computerized cryolathe carves the corneal tissue smoother and more regularly.

It must be emphasized that a 0.20 uncorrected vision provides a good mobility and some of these patients refuse to wear their overcorrection constantly.

Troutman et alii [7] admit that KP may replace the use of alloplastic materials for the correction of aphakic ametropia either as a primary or as a secondary procedure. Swinger and Barraquer [6] state that KP and KM could be useful adjuncts to the present armamentarium for optical correction. However, further research, instrument development and controlled clinical trials are necessary to demonstrate their safety and efficacy.

SUMMARY

A retrospective research study was done analysing the lamellar refractive keratoplasty — keratophakia and hypermetropic keratomileusis — as a surgical procedure for the correction of aphakic hypermetropia. The results of six keratophakias performed in the period of 1977-1981 and 62 hypermetropic keratomileusis done in 1980 are presented All the patients had a senile cataract and were subjected to a cryo-intracapsular extraction. All of them had the combined surgery, intracapsular extraction + refractive keratoplasty, with the exception of two patients. All the surgeries by the same surgeon. The hypermetropic keratomileusis results of 1980 are compared with the most recent ones after a modification in the technique.

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