The Casebeer system for predictable kerato refractive surgery: one year evaluation of 205 consecutive eyes (*)

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Purpose

This study was undertaken to document the results of current radial keratotomy surgical technology, utilizing the Casebeer Keratorefractive system. These results are contrasted to those of the PERK keratorefractive system, developed about twelve years ago.

Methods

Two hundred and five consecutive surgical procedures are examined, which as the author's first year of experience with radial keratotomy. All procedures fit within the Casebeer nomograms. Enhancement procedures were performed following the Casebeer System nomograms.

Results

Follow up for 100% of patients was achieved. Postoperative cycloplegic refractions yielded an average of $+0.27 \pm 0.58$D of residual refractive correction with a range of -0.88D to $\pm$ 2.50D. 20/25 or better uncorrected visual acuity was achieved one year postoperatively in 86% of patients and 20/40 or better uncorrected acuity was achieved in 99% of patients. Bothersome but not incapacitating side effects glare, starbursting and fluctuating vision, as has been commonly observed in the past with radial keratotomy. 98% of surveyed patients stated that they were satisfied with their resultd and 99% said they would have radial keratotomy again if they had the choice.

Conclusion

The Casebeer System for keratorefractive surgery which is easy to learn can yield an extremely accurate surgical result. The major reason for increased accuracy compared to the PERK system is the surgeon's ability to titrate the primary surgical procedure with enhancement operations. Althoug radial keratotomy is by no means a perfect surgical technique, side effects tend to be relatively minimal and patient satisfaction tends to be extremely high.

Introduction

Radial Keratotomy (RK) surgery, as we now it, is derived largely from the clinical work of Fyodorov in the mid 1970's[1] In the United States the most critical analysis of radial keratotomy has been performed under the auspices of the PERK study[2-4], which continues to generate meaningful data, however, reflecting a somewhat rudimentary approach to this keratorefractive procedure.

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During the decade since the initiation of the PERK study, numerous advances in technology and newer systematic approaches have enabled keratorefractive surgeons to generate a far more predictable surgical result. Several "systems" of keratorefractive surgery have appeared during this time due to the work of investigators such as Salz[5], Deitz[6], Marks[7], Arrowsmith[8], Thornton[9] and others. All of their approaches differ significantly from the basic premise on wich the PERK study was developed and conducted. In this paper we will be examining the performance of another system, the Casebeer System, and comparing these results to the PERK data to illustrate some of the areas of advancement which have been achieved during the 1980's. A consecutive series of 205 eyes will be evaluated. These procedures represent the first one year's clinical experience with radial keratotomy for one of the authors (TPW).

Materials and Methods

Two hundred and five consecutive radial keratotomy procedures on 125 patients were performed between September 4, 1990 and September 3, 1991 using the Casebeer System for keratorefractive surgery. All procedures and follow up care were performed by a single surgeon (TPW) and his technical staff. The average age for this patient population was 38.4 ± 8.6 years with a range of 22 to 62 years. One hundred and fourteen female eyes and 91 male eyes were operated on. All patients had an extensive ophthalmic examination prior to surgery, with discussion of alternative procedures, indications, and contraindications for the RK procedure. All signed appropriate informed consents regarding the surgery. Enhancement procedures, when performed, were based on the patient's desire to improve the refractive result and a realistic chance that surgical improvement was feasible using the Casebeer System.

All patients had cycloplegic and non-cycloplegic refractions in a 20 foot lane using a TVA (Model TVA1073 by Technical Enginuities Corporation of Brea, California) video random letter projector. Cycloplegia consisted of one set of phenylephrine hydrochloride 2.5% and tropicamide 1% followed 5 minutes later by another drop tropicamide 1%. Roughly 15 a 20 minutes after the instillation of drops, cycloplegic refractions were performed. In a minority of patients the uncorrected acuity appeared to be significantly worse than the apparent refractive result i.e., 20/50 vision with a cycloplegic refraction of 0.25D. To assess this phenomena, all patients also had a "null point" refraction performed with and without cycloplegia. Here patients looked through the phoropter and all lenses were brought back to plano in order to obtain another estimate of uncorrected vision. The data presented represent the better recorded uncorrected acuity, either "null point" or ordinary "uncorrected". Acuities were recorded down to the 20/20 level only. No testing either pre or postoperatively was performed below 20/20. For average acuity calculations, acuity data was converted to decimal notation (i.e. 20/40 = 0.5) and averaged. Some author [10] have suggested using the log the decimal notation to average acuities. We found no significant difference in results whether a log or simple decimal calculation was used in averaging this limited range of visual acuities (Table 1). Therefore single decimal calculations were used for analysis. In orden to be scored at 20/40, 20/30, etc. the patient must have read the majority of letters on the 20/40, 20/30, etc. test line (at least 3 of 5 letters).

Table 1
Uncorrected vision one year after radial keratotomy
Log average calculation compared to decimal average calculation

	Myopic Range	Mean Decimal	Acuity Decimal	Acuity Log
1mo	-2.00 to -3.12	0.80	20/25	20/26
	-3.25 to -4.27	0.82	20/24	20/25
	-4.50 to -8.00	0.78	20/26	20/27
	outside PERK*	0.78	20/26	20/28
3mo	-2.00 to -3.12	0.88	20/23	20/23
	-3.25 to -4.27	0.80	20/25	20/26
	-4.50 to -8.00	0.82	20/25	20/26
	outside PERK	0.76	20/26	20/28
1Yr	-2.00 to -3.12	0.88	20/23	20/23
	-3.25 to -4.27	0.85	20/24	20/24
	-4.50 to -8.00	0.84	20/24	20/22
	outside PERK	0.78	20/26	20/26

We attempted to distributed a questionnaire at all of the patient's one year follow up appointment and were able to tabulate a response in 79% of patiens. Although a number of questions were asked in the questionnaire, the main issues addressed were patient satisfaction, and whether they would have radial keratotomy again, had they never had the procedure in the first place.

Surgery was performed under topical 4% lidocaine anesthesia, 15 minutos after 20 mg of diazepam had been administered orally. The Magnum Diamond "System" blade was used for the surgery and Chiron IntraOptics "System" markers were used during all procedures. The Sonogage ultrasound pachometer was used to measure corneal thickness, just prior to the procedure with the patient on the operating room table, 1.5 mm temporal to the light reflex on the cornea. The Casebeer nomograms were adhered to for all primary procedures and the description of enhancements (The Casebeer nomograms are propietary and are available through Kerasys International, Scottsdale, Arizona), as per the Casebeer System were adhered to for all enhancement procedures.

In brief, the Casebeer nomograms requiere optical zones between 2.75mm and 5.0 mm for myopía and 4.50 mm and 7.0 mm for paired astigmatism T cuts. Between and 16 incisions are performed. The Magnum Diamond System blade is set to 100% of pachymetry measured 1.5 mm temporal to the corneal light reflex. Radial incisions are performed from the limbus towards the central optical zone starting inside the vascular arcades. T cut incisions, either 2.5 mm or 3.00 mm in length, are performed with the diamond blade set at the paracentral pachymetry as for the radial incisions.

Cycloplegic refractions were used as the basis for all primary and enhancment procedures. Preoperative myopic corrections were between +0.75D and -8.87D (spherical equivalent) with an average of -3.92 $\pm$ 1.80D. Primary astigmatic corrections, were attempted in 85 of the 205 surgical procedures with a range of 1.0D to 5.0D and an average of 2.07 $\pm$ 1.08D. All patients were followed for a minimum of one year postoperatively and data tabulated for one month, three months and one year after the last surgical procedure, either primary or enhancement. Mean, standard deviation, and range were calculated for all time periods following surgery Measurements of uncorrectec visión, refraction and cycloplegic refraction were made on most preoperative visits. Additionally, data was broken down intc groupings similar to that of PERK for purposes of comparison. Statistical comparisons between PERK and "Casebeer" systems were performed using the student's T test.

In order to obtain a complete follow up data patients were reimbursed for their time and travel ($25.00) by Chiron IntraOptics for their one year postoperative cycloplegic evaluation.

Although well over a year elapsed between the time of the primary procedure on the last patient in this study (September 1991) and the execution of the data analysis (October 1992), not all patients had one year follow up after their last enhancement procedure bacause a small number of patients continued to have enhancement procedures during that time period. The data reflects the last possible time point, after the last enhancement, given either a one, three or twelve month follow up time period. One hundred percent of patients operated on in this study were available for follow up examination. However, ten patients did not have cycloplegic refraction at their last examination time period. This was primarily because their uncorrected vision was good and they were unwilling to undergo cycloplegia and refractions. In an effort to obtain complete follow up on all patients, lane refractions, only, were recorded at the one year time point when patients refused cycloplegic refraction. In these situations, the cycloplegic results of the previous postoperative time period, generally at 3 months, were utilized for data analysis. Additionally, three patients who were doing well postoperatively, who had either moved out of our area or simply did not have the time to come into the office were tested in an unconventional manner. For one patient an eye chart was mailed to the patient with instructions on how to test their vision, along with coaching by telephone. For two other patients, one of the authors (TPW), personally visited the patients at

work to test their vision.

During the one year of this study, 205 eyes in 125 patients (total 250 eyes) had radial keratotomy for myopia and/or astigmatism and had a desired correction of plano.

Thirty four eyes (out of a total 250 eyes) within this population were corrected for monovision, with a less than 20/20 distance refractive result planned, or had mild amblyopia such that their best corrected vision was less than 20/25 preoperatively. These eyes (out of a total 250 eyes) had no surgery performed. In addition, two of the 205 eyes still required enhancement procedures but had not had the time to undergo these procedures at the time of data tabulation and therefore were also not considered in the data analysis. The enhacement procedures required for these two eyes were similar to those for other enhanced patients and therefore the results are expected to be comparable to the rest of the population. This left 203 eyes, all corrected for distance vision, that were available for analysis. Of the 203 eyes. One hundred and fifty seven met the criteria required for entrance into the PERK study and their results were compared to the original 411 PERK study eyes (one year analysis). In addition, the entire population of 203 eyes were analyzed separately in order to reflect the range of therapeutic capability described within the Casebeer Keratorefractive System.

In order to study diurnal fluctuation we surveyed 75 eyes (random volunteers from 125 patient group) where cycloplegic refractions were performed roughly 6 to 7 hours apart for each of these eyes. All eyes studied for diurnal fluctuation were at least one year postoperative after their last surgical procedure (primary or enhancement).

Results

Of the 203 study eyes, 139 eyes had only primary procedures and 66 eyes required primary plus enhancement procedures (33%). Table 2 reflects the number of enhancements required in this study. Of the 203 eyes, 3 eyes have had only

Table 2
Enhancement procedures

Number Eyes	Number Enhancements
139	None
43	One
17	Two
3	Three
2	Four
1	Seven
2	Pending*

* Enhancement on two eyes will be necessary, but were not done by the time of the data analysis.

one month follow-up, 28 eyes three months follow-up and 172 eyes one year follow-up. No eyes have been lost to follow-up. At one year after the primary plus enhancement procedures for each of the 203 eyes, the average residual cycloplegic refraction was +0.27 + 0.58D with a range of -0.88 to +2.50D. Of these patients, 99% had uncorrected visual acuity of 20/40 or better and 86% were 20/25 or better uncorrected. Table 3

Table 3
Cycloplegic refraction one year after radial keratotomy

	Miopic Range	Mean	SD	N	Range
1mo	-2.00 to -3.12	-0.21	0.40	48	-1.25 to +0.75
	-3.25 to -4.27	-0.07	0.57	34	-1.50 to +1.50
	4.50 to -8.00	-0.06	0.61	56	-1.25 to +1.75
	outside PERK*	+0.13	0.67	39	-1.00 to +1.75
3mo	-2.00 to -3.12	+0.02	0.46	46	-1.25 to +1.50
	-3.25 to -4.37	-0.04	0.65	37	-1.50 to +1.75
	-4.50 to -8.00	+0.04	0.49	61	-1.00 to +1.25
	outside PERK	+0.27	0.53	44	-1.00 to +1.50
1yr	-2.00 to -3.12	+0.19	0.55	48	-0.75 to +2.00
	-3.25 to -4.37	+0.15	0.52	31	-0.88 to +1.50
	-4.50 to -8.00	+0.25	0.58	52	-0.75 to +2.50
	outside PERK	+0.39	0.58	31	-1.00 to +1.50
1yr**	Total PERK	+0.23	0.58	157	-0.88 to +2.50
	Total Casebeer	+0.27	0.58	203	-0.88 to +2.50

* Study patients who did not fit PERK inclusion criteria.
** One year cycloplegic data plus last cycloplegic data (3mo) where patients did not have one year cycloplegic exam.

summarizes the one month, three months and one year results of cyclopegic refraction for all patients, after primary and enhancement procedures where

applicable. The one year residual non-cycloplegic refraction was -0.11 ± 0.52D with a range of -1.12 to +2.00D (Table 4) after primary and enhancement procedures. One year average acuity was 0.83 ± 0.17 with a range of 0.20 to 1.00 (Table 5).

Table 4
Refraction without cycloplegia 1 year after radial keratotomy

	Miopic Range	Mean	SD	N	Range
	-2.00 to -3.12	-0.40	0.44	48	-1.25 to +0.75
1mo	-3.25 to -4.27	-0.32	0.55	37	-1.50 to +1.25
	-4.50 to -8.00	-0.33	0.58	61	-1.75 to +1.25
	Outside PERK*	-0.17	0.65	45	-2.00 to +1.75
	-2.00 to -3.12	-0.21	0.38	51	-1.00 to +1.00
3mo	-3.25 to -4.37	-0.25	0.55	37	-1.50 to +1.00
	-4.50 to -8.00	-0.36	0.57	62	-1.75 to +1.75
	Outside PERK	-0.15	0.49	45	-1.50 to +1.25
	-2.00 to -3.12	-0.11	0.46	49	-1.12 to +1.00
1yr	-3.25 to -4.37	-0.24	0.48	31	-1.00 to +0.88
	-4.50 to -8.00	-0.12	0.60	52	-0.75 to +2.00
	Outside PERK	-0.05	0.60	31	-1.00 to +1.40
1yr**	Total PERK	-0.14	0.50	157	-1.12 to +2.00
	Total Casebeer	-0.11	0.52	203	-1.12 to +2.00

* Study patients who did not fit PERK inclusion criteria.
** One year cycloplegic data plus last cycloplegic data (3mo) where patients did not have one year cycloplegic exam.

Astigmatic corrections were performed on 4 eyes as part of the primary procedure and on 18 eyes during enhancement procedures. Overall the residual astigmatism one year postoperatively was 0.19 + 0.43D with a range of 0.0 to 1.75D.

Some patients with less than 20/25 or 20/30 uncorrected vision did not request enhancements even though they could have additional surgery. In order to evaluate this issue, we looked at the best corrected eye in the 125 patients that were included in the study. Ninety percent of these patients had at least 20/25 or better vision in one eye and 99% had at least 20/40 or better vision in one eye.

A number of side effects, such as starbursting, decreased visual acuity in low light conditions and variable vision throughout the course of the day were reported. Although a number of patients

Table 5
Uncorrected vision+ One year after Radial Keratotomy

	Miopic Range	Mean	SD	N	Range
	-2.00 to -3.12	0.80	0.19	48	0.26 to 1.0
1mo	-3.25 to -4.27	0.82	0.17	37	0.27 to 1.0
	4.50 to -8.00	0.78	0.18	61	0.34 to 1.0
	Outside PERK*	0.78	0.20	44	0.26 to 1.0
	-2.00 to -3.12	0.88	0.14	47	0.33 to 1.0
3mo	-3.25 to -4.37	0.80	0.13	31	0.42 to 1.0
	-4.50 to -8.00	0.82	0.17	62	0.33 to 1.0
	Outside PERK	0.76	0.17	44	0.33 to 1.0
	-2.00 to -3.12	0.88	0.14	52	0.50 to 1.0
1yr	-3.25 to -4.37	0.85	0.18	34	0.24 to 1.0
	-4.50 to -8.00	0.84	0.16	52	0.20 to 1.0
	Outside PERK	0.78	0.19	34	0.31 to 1.0
1yr**	Total PERK	0.85	0.16	157	0.20 to 1.0
	Total Casebeer	0.83	0.17	203	0.20 to 1.0

+ Decimal notation, 20/20 = 1.0, 20/40 = 0.5, etc.
* Study patients who did not fit PERK inclusion criteria.
** One year cycloplegic data plus last cycloplegic data (3mo) where patients did not have one year cycloplegic exam.

described difficulties under low light conditions, we did not attempt to tabulate the overall incidence of this problem. However, for all but a handful of patients, this did not appear to be a significant problem. In the 75 eyes evaluated for diurnal fluctuation, the mean change morning to evening was 0.05D with a standard deviation of 0.45D and a range of -1.0 to + 1.0D. This was not statistically significant. Twenty five percent of these patients became more myopic by a half diopter or less. only 3% became more myopic by greater than 0.5D and less than 1.0D and no patient had more than a one and one quarter diopter gain in myopia. Conversely, 17% of patients became less myopic by 0.5D or less, and 4% of patients became less myopic by greater than 0.5 and less than 1.0D. No patient became less myopic by greater than one and one quarter diopters.

Change in cycloplegic refraction from 3 months to one year was evaluated in the 120 eyes which had no surgical procedures performed during this time period and which had cycloplegic refraction at 3 months and at one year. The mean change was -0.22D (gain of surgical effect) with a standard deviation of 0.45D and a range of -1.25 to + 0.88D.

With paired analysis, there was a statiscally significant difference between the 3 month and one year observations.

Twenty one percent of patients gained more than one half of a diopter of effect. Four percent of patients gained more than one diopter of effect. Zero percent gained more than one and half diopters of effect. Conversely, two percent of patients lost more than a half a diopter of effect and no patient lost more than one diopter of effect during this follow up period.

Because this small hyperopic shift was noted during the first year postoperatively we examined those patients where we had cycloplegic refraction at 3 months, 1 year and 2 years, 13 eyes in all. In this small group of patients there was a 0.47D hyperopic shift (statiscally significant), between 3 months and 1 year and a 0.17D shift (not statistically significant), between one year and two years. Thus it would appear that a decreasing hyperopic shift as a function of time is ocurring.

We also attempted to look at the distribution of patients with the hyperopic shift in terms of their age and/or their degree of myopia. This is demonstrated in Table 6. There did not appear to be any obvious correlation between either degree of myopia or age and the phenomena of progressive hyperopia.

Table 6
Hyperopic Shift One and two years after Radial Keratotomy

		No. Eyes	Age
1yr.	-2.00 to -3.12	3	40.1
0.5D	-3.25 to -4.27	6	35.9
to	4.50 to -8.00	7	35.0
1.0D	outside PERK	3	47.5
2yr.	-2.00 to -3.12	3	38.3
0.5D	-3.25 to -4.37	1	24.6
to	-4.50 to -8.00	1	38.6
1.0D	Outside PERK	-	-
1yr	-2.00 to -3.12	1	22.8
1D	-3.25 to -4.37	2	41.2
	-4.50 to -8.00	2	31.0
	Outside PERK	-	-
2yr	-2.00 to -3.12	-	-
1D	-3.25 to -4.37	3	36.5
	-4.50 to -8.00	-	-
	Outside PERK	-	-

Ninety eight percent of patients responding to our questionnaire stated that they were satisfied with the surgical result and 99% said that if they had to consider radial keratotomy as if they had never had the procedure done, they would again have the surgery performed.

Discussion

In general, these data support the conclusion that the accuracy of keratorefractive surgery as it is now performed has a standard deviation of roughly one half diopter. This is consistend with the observation that 99% of patients in the study have 20/40 or better uncorrected vision.

If only primary procedures are considered, the accuracy is significantly less, with a standard deviation of 0.92 diopters. This is similar to the PERK data (SD 1.2D)[5] For PERK, 74% of patients were 20/40 or better uncorrected and in our study, 71% were 20/40 or better after the primary procedure alone. PERK patients were generally not enhanced, and in fact, enhancements were discouraged. When enhancements however are included, our data demonstrate a much higher degree of accuracy with a standard deviation of 0.58D. This is stastically significantly more accurate than either the PERK results or our without enhancement. Therefore, the ultimate benefit of keratorefractive surgery as currently practiced, is only achievable by virtue of the fact that these procedures can be titrated through surgical enhancement procedures which form an integral and crucial aspect of this surgical technique. Without enhancement procedures, the relative accuracy of keratorefractive surgery approaches that in OIL surgery with a standard deviation of approximately one diopter [11].

One reason why a patient may not request an enhancement procedure in an eye which is in the 20/30 or 20/40 range has been that the fellow eye has excellent vision, enough to allow normal

function. If the 20/30 or 20/40 eye is slightly under corrected, generally the patient would be encouraged to leave it that way given the possibility of progressive hyperopia.

It is obvious that radial keratotomy has been in a state of evolution for several decades. The PERK study was one of the initial critical clinical evaluations of this surgical procedure. However, the PERK surgeons were limited by a protocol which is now out of date, and by instrumentation that is primitive compared to current techonology. Factors such as age were not a consideration in the PERK protocol whereas in almost all systems that are now in use, age plays an important role in planning and prediction of surgical results. Therefore it is not surprising that the PERK data do not compare favorably to data generated by current radial keratotomy systems. In assesing or comparing any type of keratorefractive surgery to radial keratotomy (i.e.., the excimer laser)[12-16] it imperative to look not at the historical perspective represented by the PERK data, but rather to utilize radial keratotomy results reflecting current RK technique. Surgeries that suport to have comparable accuracy to radial keratotomy therefore must demonstrate standard deviations or accuracies of 0.5 diopters or less, with uncorrected visual acuity of 20/40 or better in well over 95% of patients. The 1.2 diopter demonstrated in PERK study is not acceptable as a current standard.

Concerns about radial keratotomy surgery that still exist and are completely addressed by these data are those of the possible progressive effect of the surgery with time, as was demonstrated by Deitz and others [17] Even with only one year data of follow up, however a slight (but statistically significant) hyperopic shift of 0.22D, was noted. This suggests that patients are best left slightly uncorrected. Additionally, difficulties with low light visual distortion, particularly with the higher myopic corrections, are important issues that were not analyzed critically in this work. However, no significant clinical problem has resulted in either of these areas in nay of the patients reported.

Another concern regarding radial keratotomy is the incidence and severity of diurnal fluctuation in this study. Three percent of the 75 eyes examined showed a myopic shift of between 0.5 and 1.0D. This is significantly less than the 42% of myopic shift demonstrated by the PERK study[18] at their one year evaluation. However the PERK evaluation was done with manifiest refraction in select patients who were symptomatic of fluctuating vision while the current study used exclusively cycloplegic refraction, in randomly selected patients; this perhaps may account for the smaller refractive change in the current study. Overall in our patient population there were very few significant clinical symptoms related to long term fluctuation of vision after surgery. Therefore, the authors feel that although this problem can be measured in certain induviduals, it does not pose a significant clinical concern for most radial keratotomy patients.

Although 99% of the patients studied in this series had 20/40 or better uncorrected vision and similarly 99% said that if they had to do it all over again, they would have radial keratotomy performed, nevertheless 14% of patients were less than 20/25 uncorrected and some of these patients required spectacles at least part of the time in order to function comfortably (Table 7). While these data

Table 7
Uncorrected vision*
203 eyes - 1 year follow up

20/20	49%
20/25	86%
20/30	96%
20/40	99%

* Read majority of letters per line.

clearly identify RK as the most accurate refractive surgical procedure yet developed, it is not perfect. A procedure with better refractive accuracy and fewer side effects, would be preferable, if it could be developed. The plus or minus one half diopter accuracy of radial keratotomy provides twice the predictability of cataract/IOL surgery, but for refractive accuracy to be satisfactory for virtually all activities and comparable to glasses or contact lenses, in virtually all patients, a quarter diopter standard deviation, resulting in 99% of patients 20/25 or better uncorrected would be necessary. Additionally problems related to presbyopia are

poorly handled with radial keratotomy, but are very important given the average age of 38 years in the RK population. Mono vision is a solution for only some patients. The ultimate surgical refractive technique must also deal with this issue.

The outcome of 99% 20/40 or better uncorrected acuity is a higher level of success than has been generally reported for radial keratotomy. A number of factors contribute to this success. All patients treated in this study were told at the outset that any and all enhancement procedures would be covered under the initial surgical fee. Any enhancement that could safely improve their final vision, without risking over correction would be performed at no extra charge. Therefore, many patients in the study felt that they were entitled to additional surgery, even if their visual deficit by most standars was fairly small. Had their been some financial dis-incentive to enhancement procedures, undoubtedly the number of enhancements would have been far less, but the uncorrected acuity would have also suffered slightly. In order to avoid undue enthusiasm for continued enhancement procedures on the part of the patients, patients were thoroughly informed regarding the possibility that additional surgery could likely make the uncorrected vision worse. This dissuaded many patients from demanding inappropriate enhancements.

Enhancement procedures offer the ability to both increase the effect of surgery as well as reduce the effect of surgery (suture enhancements). In fact, six suture enhancements were performed during the course of this study.

These, based on the ability to perform enhancements. 99% "sucess rate " is not at all unreasonable. In fact, the 3 eyes which had less than 20/40 uncorrected vision, could, in fact, be enhanced to the point that their uncorrected vision would be better thaan 20/40. However, these 3 patients were asymptomatic and felt that their vision was acceptable, further enhancement procedures were not encouraged.

One would predict that the ideal surgical refractive result would be a patient who is slightly under corrected, specifically a spherical equivalent of between -0.75 to -0.50D. If the surgeon is lucky enough to have both eyes at that level of correction, generally the patient will be extremely satisfied with the result. However, it has been our experience that many patients, when one eye is corrected to between -.50 and -.75 and the other eye is plano (manifiest refraction), some patients may be extremly dissatisfied with the imbalance. Although, because of the issue of progressive hyperopia, the surgeon realizes that enhancing the under corrected eye is probably a mistake, sometimes the issue is difficult to handle diplomatically.

Another somewhat unusual refractive result was also commonly observed. Take, for example, a 52 year old patient whose right eye has a manifiest refraction postoperatively, spherical equivalent of -0.50D and the left eye a manifiest refraction of plano. The same patient has a cycloplegic refraction generally of plano in the right eye and +0.50 to 0.75D in the left eye. We would have guessed that the patient would be more satisfied with the visual result in the right eye, but almost universally, patients irrespective of age with this refractive result, prefer what we would think is the slightly over corrected left eye. In general, the cycloplegic refractions yielded +0.50 to +0.75D more refractive power than the manifest refractions. This issue in some patients is so significant that the patient is anxious to have the eye with the plano cycloplegic refraction enhanced. Obviously from a surgical prospective this is never done.

Several major variables still exist regarding radial keratotomy, such as the uniformity of the incision depth, the skill of the surgeon, the healing parameters of the patient's cornea, to name a few. The surgeon's skill is difficult to control, but is generally acquired in a fairly short time period, even for opthalmic surgeons with little or no clinical corneal surgical experience. The variable healing paramenters of the cornea, to date have eluded precise control, although some pharmacological intervention has been tried, without consistent effect. The diamond cutting instrument used for current radial keratotomy surgery has evolved considerably since the steel cutting blades of a decade ago. However, there still is a degree

of variability in the uniformity of depth of the corneal incisions. This is largely due to then non-uniform thickness of the cornea which shows increasing thickness as one measures from the center to the periphery of the normal cornea. Also the temporal portion of the cornea is generally thinner than the nasal aspect of the cornea. Given the fact that most current RK surgical techniques dicate that the diamond blade is only set at one thickness for all radial incisions, the distance between the tip of the blade and the endothelium must therefore vary along the course of the incision from limbus to optical zone. Work is currently under way (in conjunction with Dr. Alex Dybbs, Sonogauge, Inc.) to develop a diamond blade (Smartknife) which is able to ultrasonically sense the position of the endothelium relative to the tip of the cutting instrument and adjust itself along the course of the incision, such that a uniform depth of cut can be obtined for the entire excursion of each of the radial or T incisions. The distance between the tip of the diamond blade and the endothelium could be preset depending on the surgeon's preference or clinical experience. Such a cutting device would assure a uniform incision depth (distance between the base of the incision and the endothelium) which is currently impossible given today's technology.

Keratorefractive surgery, as currently performed, can satisfy the vast majority of myopic and astigmatic patients. Current radial keratotomy techniques allow correction of up to 8 diopters of myopia and 6 diopters of astigmatism, with roughly a 0.5 diopter standard deviation. This assures up to 99% of patients 20/40 or better uncorrected vision and up to 86% of patients to 86% of patients 20/25 or better uncorrected vision.

Higher degrees of myopia, not treatable with radial keratotomy prcedures, constitute an extremely small percentage of the myopic population, perhaps only one to two percent. It is critical to realize that any evolving technology which may replace radial keratotomy must offer a higher degree of accuracy and/or a wider range of applicability in order to be an acceptable alternative. Furthermore, cost considerations would require any new technology to be cost effective, in comparison to radial keratotomy. Given these considerations the authors feel that radial keratotomy will remain the major kerato-refractive procedure for routine ophthalmic use for the immediate future.

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