Deepening of Incisions After Radial Keratotomy Using the “Tickle” Technique

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ABSTRACT: Since the introduction of radial keratotomy, accurate incision depth has been difficult to achieve with any corneal knife. To assure repeatable depth of incisions and to adjust the refractive effect of these incisions after the surgery, I have developed a series of techniques that are described in this article and that I refer to as “tickles” in discussion with the patients. Seventeen eyes, from a consecutive series of 102 operations (reoperation rate of 17%), underwent complete opening and/or deepening of undercorrected eight-incision radial keratotomy. This was performed in the immediate postoperative period (3.0 ± 4.2 months), at the slit-lamp microscope, without peripheral deepening or extension of the optical zone. After the initial radial keratotomy, the average spherical equivalent refraction was -2.04 ± 0.68 D; after opening and/or deepening the incisions, the average spherical equivalent refraction was -0.53 ± 0.24 D. The average effect of this procedure was a reduction in myopia of 1.51 D. All 17 eyes had a final refraction between -0.25 and -1.00. (Refract Corneal Surg 1991 7:348-355.)

Radial keratotomy, as introduced by Sato in the 1940s has evolved from an operation requiring 32 radial incisions configured about the optical axis to eight or fewer incisions in the majority of cases. Fyodorov observed that 16 incisions in 546 eyes gave an average of 2.77 D of effect and that 32 incisions performed in 22 eyes gave only 2.79 D of effect. The low amount of corrected myopia in this early study was a reflection of the shallow incisions produced with metal blades set to create 75% corneal thickness incisions. As crystalline blades replaced metal blades, the incision depth has become more predictable. The amount of myopia corrected became greater and it was demonstrated that 16 deep incisions gave only 10% more effect than eight deep incisions; the potential complications from 16 incisions did not justify the small additional effect.

Radial keratotomy has been examined in several large series evaluating the safety, efficacy, predictability, stability, and patient satisfaction. The progressive and regressive changes have been documented. Variability of refractive result seems to be an inevitable part of radial keratotomy no matter how carefully the original operation is performed. Shallow incisions account for at least a portion of the variability, particularly with beginning surgeons, although variability in wound healing may also play a role.

Deepening of incisions following radial keratotomy in the operating room is a difficult procedure due to poor visualization of the incisions with standard operating microscope frontal lighting. One approach has been to dilate the pupil and examine the incisions with retroillumination, however this usually requires a retrobulbar block due to the bright
light, and visualization still remains suboptimal. Conceptually, the idea of deepening or opening incisions is attractive since, in many cases, shallow incisions or incisions which have healed too rapidly are the cause for undercorrections. Corneal instability, similar to that observed with the Ruiz procedure, has been reported both by myself (International Society of Refractive Keratoectomy Annual Pre-Academy Meeting, October 28, 1989, New Orleans, La) and others in radial keratotomy with more than eight radial incisions. For these reasons, I prefer to open the primary incisions of an undercorrected eight-incision radial keratotomy at the slit-lamp microscope rather than to deepen or add additional incisions in the operating room.

This article discusses various approaches to opening incisions at the slit-lamp microscope and will present data on 17 eyes from a consecutive series of 102 radial keratotomies, which have undergone complete opening and/or deepening of the primary eight incisions.

**TECHNIQUE**

A series of surgical techniques to modify the incisions of the undercorrected radial keratotomy patient are shown in flow chart form in Figure 1. Appropriate selection of technique depends upon careful observation of existing incisions and upon the patient’s refractive error. The incisions should appear as though they extend through 100% of the cornea at the edge of the optical zone as illustrated in Figure 2.

**Squaring the Paracentral End of Incision**

If the eye is mildly undercorrected (approximately 1.00 D) and if the incisions appear deep, it is possible that the undercorrection is due to rounded entry at the optical zone of a knife that has a single angled cutting edge. This problem has been discussed by Franks. Additional correction can be obtained by opening the incision approximately 2 to 3 mm adjac-
“Tickle” Technique/Buzard

Figure 3: (A) Configuration of incision produced with single oblique-bladed diamond knife drawn from optical zone to limbus and appearance after procedure (“tickel cut addition”) to square the paracentral end of the incision. (B) Frontal view of cornea showing 2- to 3-millimeter opening of incision (“tickel cuts”) adjacent to the optical zone.

cent to the optical zone and squaring the incision (Fig 3). In my experience, approximately 1.00 D of additional effect can be obtained with this technique.

For the initial procedure, I prefer to use a single-edged, oblique-bladed diamond knife drawn centrifugally from the optical zone to the limbus, since I believe it produces straighter incisions and obviates unwanted excursions into the optical zone. To avoid undercorrections, I routinely utilize a second double-edged diamond knife at the time of the original operation using the vertical edge to cut toward the optical zone to square the incisions. For this reason, I rarely need to perform this maneuver in the postoperative period.

Open and Deepen Entire Incision

If the incisions appear shallow, all incisions should be deepened with a double-edged diamond knife set at the original length (Fig 1). The amount of extension depends on the appearance of the incisions on slit-lamp examination; in general, it should be .03 to .05 mm. In these cases, the deepening is performed cautiously and at the first sign of microperforation, the knife is withdrawn, retracted .01 to .02 mm, and the procedure completed.

I have found shallow incisions to be particularly prevalent in young patients under the age of 35 years with firm corneas. In this age group, I utilize two diamond knives set at the same length as that during the original surgery. The first knife has a 45-degree blade and is drawn from the optical zone to the limbus to obtain straight incisions. The second knife has a 30-degree double-edged blade, and I use the vertical edge to cut from the limbus to the optical zone without fixating the eye, which allows the knife to cut easily along the bottom of the incision but tends to resist cutting virgin tissue at the end of the incision. This has been discussed previously by Bores in relation to stepped radial incisions and has been referred to by Deitz (personal communication) as “skating the wound.” Charlton has also used this technique.

Opening Deep Incisions

If the incisions appear to be adequately deep, opening the incisions with the original knife setting may still provide additional effect (Fig 1). In fact, simply opening the incisions with a blunt hook may serve the same purpose although the uncut bottom of the incision will not open without a knife. If the patient remains undercorrected, the incisions may be allowed to heal for 2 to 4 weeks and reopened with additional effect. This technique depends on the unproven concept of building up progressive layers of scar tissue which then create a larger wedge in each incision and a correspondingly progressive greater myopic correction. There seems to be a theoretical maximum effect that can be achieved and repeated opening of the incisions seems to yield less and less effect, although I have only opened incisions a maximum of three times.

Extension or Peripheral Deepening of Incision

If the aforementioned measures are unsuccessful, two additional alternatives remain to treat the undercorrected patient. These are peripheral stepped incisions and extension of the optical zone (Fig 1). These measures are required only in rare circumstances, but can be performed at the slit-lamp microscope with effective results.

SURGICAL TECHNIQUE

Topical tetracaine anesthesia is administered 5 to 10 minutes before and again immediately prior to the procedure. The patient is positioned comfortably
Figure 4: (A) Osher style diamond knife with angled head allows better visualization of diamond blade location during surgery. (B) Osher style diamond knife in use showing handle sloped away avoiding contact with the slit-lamp microscope.

at the slit-lamp microscope and the eyelids are retracted by an assistant. In a darkened room with the door closed, the patient is asked to fixate either a LED target at the end of the room or on some other convenient object. An Osher style diamond knife with an angled handle (Fig 4) is employed, because this allows convenient visualization of the exact point of entry and avoids striking the slit-lamp microscope with the knife handle. The diamond should be a “thick” double-edged blade, which is the diamond supplied with the knife by Medico. This knife will open the incision quite nicely but will have a tendency to resist cutting virgin tissue.

The knife is placed into the incision approximately 1.0 to 1.5 mm from the central end of the incision and twisted slightly which will open incisions that have been created within 1 to 2 months. Recently, I have utilized a blunt IOL hook, such as a Sinsky hook, to safely open the incision (M. Friedlander, personal verbal communication, 1990) which can then be deepened more easily with the diamond knife. If the knife is in the correct location relative to the scar, the cornea will separate and a further tactile demonstration of the appropriate location of the knife will be a “popping” sensation as the incision breaks apart. One must be careful when using this technique to retain proper orientation of the knife relative to the wound and to avoid excessive pressure since it is possible to create a “Y-shaped” bottom to the incision if these precautions are not observed. If proper care is observed, the use of the second knife does not create a second incision since the blade tends to follow the incision already in place.

Following the procedure, mydriatic and cycloplegic drops (phenylephrine 2.5% and tropicamide 1%) are instilled to reduce iris and ciliary muscle spasm and to reduce conjunctival injection, improving both the immediate cosmetic appearance and postoperative irritation. A disposable soft contact lens is commonly inserted. Postoperative medications include a steroid-antibiotic combination four times daily and a thin artificial tear every hour while awake. The patient is seen the next day at which time the contact lens may be removed depending upon comfort and healing. This technique maximizes the patient’s comfort and cosmetic appearance following the procedure and represents the same technique which I utilize following the primary procedure. In this manner, the patient views both the original radial keratotomy and subsequent opening of the incisions as minor procedures that do not significantly disrupt their daily activities. In the normal course of events, the patient will experience an immediate improvement in vision following these procedures.

**PATIENTS AND METHODS**

Seventeen eyes of 13 patients, selected from a consecutive series of 102 eyes, that received radial keratotomy had an undercorrection representing a reoperation rate of 17% (Table). The initial surgeries were standard eight-incision radial keratomies performed with a standard technique using a 45-degree single-edged diamond knife from optical zone to limbus without complications by the same surgeon. Each incision was “squared” at the portion of the incision closest to the optical zone using a double cutting 30-degree diamond knife as described above. Following the radial keratotomy, the vision without correction was found to be unacceptable in the postoperative period (Fig 5) with refractive results shown in Figure 6. The time elapsed between the original procedure and the “tickle” procedure was never less than 2 weeks (Fig 7). The incisions were opened/deepened according to the procedures noted above and, if acceptable, refraction and vision was not obtained after 2 to 4 weeks the procedures were repeated. The Table includes the number of procedures performed on each eye; no extension of the incisions into the optical zone or peripheral deepening was performed.

**RESULTS**

The spherical equivalent refraction of the eyes before and 2 weeks following the “tickle” is shown in Figure 6. More procedures are represented than the
Table
Results of Reoperation in 17 Eyes With Uncorrected Eight-Incision Radial Keratotomy

<table>
<thead>
<tr>
<th>Eye</th>
<th>Age</th>
<th>Sex</th>
<th>Preop Spherical Equivalent Refraction (D)</th>
<th>Optical Zone Equivalent Diameter (mm)</th>
<th>Postop Spherical Equivalent Refraction (D)</th>
<th>Number of &quot;Tickled&quot;</th>
<th>Final Spherical Equivalent Refraction (D)</th>
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<tbody>
<tr>
<td>1 OD</td>
<td>57</td>
<td>M</td>
<td>-4.12</td>
<td>3.75</td>
<td>-2.00</td>
<td>1</td>
<td>-0.50</td>
</tr>
<tr>
<td>2 OS</td>
<td>57</td>
<td>M</td>
<td>-4.25</td>
<td>4.00</td>
<td>-1.62</td>
<td>2</td>
<td>-0.50</td>
</tr>
<tr>
<td>3 OD</td>
<td>41</td>
<td>F</td>
<td>-5.00</td>
<td>3.50</td>
<td>-3.12</td>
<td>2</td>
<td>-0.62</td>
</tr>
<tr>
<td>4 OS</td>
<td>57</td>
<td>F</td>
<td>-7.50</td>
<td>3.00</td>
<td>-3.25</td>
<td>2</td>
<td>-0.62</td>
</tr>
<tr>
<td>5 OD</td>
<td>57</td>
<td>F</td>
<td>-7.75</td>
<td>3.00</td>
<td>-2.50</td>
<td>2</td>
<td>-0.75</td>
</tr>
<tr>
<td>6 OD</td>
<td>48</td>
<td>F</td>
<td>-5.37</td>
<td>3.25</td>
<td>-2.00</td>
<td>1</td>
<td>-0.50</td>
</tr>
<tr>
<td>7 OS</td>
<td>48</td>
<td>F</td>
<td>5.25</td>
<td>3.25</td>
<td>-1.87</td>
<td>3</td>
<td>-0.25</td>
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<tr>
<td>8 OD</td>
<td>34</td>
<td>F</td>
<td>-4.50</td>
<td>3.25</td>
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<td>1</td>
<td>-0.37</td>
</tr>
<tr>
<td>9 OD</td>
<td>32</td>
<td>F</td>
<td>-6.25</td>
<td>3.00</td>
<td>-3.25</td>
<td>2</td>
<td>-1.00</td>
</tr>
<tr>
<td>10 OS</td>
<td>32</td>
<td>F</td>
<td>-6.25</td>
<td>3.00</td>
<td>-1.50</td>
<td>1</td>
<td>-0.25</td>
</tr>
<tr>
<td>11 OS</td>
<td>27</td>
<td>M</td>
<td>-6.00</td>
<td>3.00</td>
<td>-1.75</td>
<td>1</td>
<td>-0.12</td>
</tr>
<tr>
<td>12 OS</td>
<td>32</td>
<td>M</td>
<td>-3.75</td>
<td>3.50</td>
<td>-1.50</td>
<td>1</td>
<td>-0.50</td>
</tr>
<tr>
<td>13 OS</td>
<td>38</td>
<td>F</td>
<td>-4.00</td>
<td>3.50</td>
<td>-2.00</td>
<td>1</td>
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</tr>
<tr>
<td>14 OD</td>
<td>23</td>
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<td>-3.00</td>
<td>3.50</td>
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<td>-0.75</td>
</tr>
<tr>
<td>15 OS</td>
<td>26</td>
<td>F</td>
<td>-4.00</td>
<td>3.25</td>
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<td>1</td>
<td>-0.50</td>
</tr>
<tr>
<td>16 OS</td>
<td>31</td>
<td>F</td>
<td>-4.00</td>
<td>3.75</td>
<td>-1.00</td>
<td>2</td>
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</tr>
<tr>
<td>17 OD</td>
<td>31</td>
<td>F</td>
<td>3.87</td>
<td>3.50</td>
<td>-2.37</td>
<td>1</td>
<td>-0.25</td>
</tr>
</tbody>
</table>

Average (D)
- 2.04
± 0.53

Figure 5: Visual acuity without correction before and after opening/deepening of incisions in 17 eyes.

17 eyes in the study, because several of the eyes underwent more than one additional procedure. This can be seen by the listing of patient number beneath the appropriate data; the final results are listed in the Table. The time elapsed from the original radial keratotomy to the first intervention is seen in Figure 7. In several eyes, the refraction continued to drift in a myopic direction after 2 weeks and before the subsequent "tickled" as seen in Figure 6. The final uncorrected visual acuity and the uncorrected visual acuity before the additional procedures are shown in Figure 5. All eyes concluded this study...
with an uncorrected visual acuity of 20/40 or better.

Figure 8 shows the average change in spherical equivalent refraction from the preoperative value to that at 1, 3, 6, and 12 months. Of these 17 eyes followed for 1 year, one case showed regression of 1.50 D and the remainder did not change by more than 1.00 D from 3 months to 1 year after the "tickle." From a clinical standpoint, the patients' uncorrected visual acuity and spherical equivalent refraction appeared to stabilize at 1 to 2 months. The data further indicate that small corrections, less than 1.00 D, should not be attempted before 1 to 2 months, since an additional shift in the hyperopic direction may occur in the normal process of healing.

Eyes were followed carefully for evidence of wound healing instability and none showed fluores-
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Figure 8: Average change in spherical equivalent refraction from preoperative value to value at 1, 3, 6, and 12 months following final opening/deepening procedure.

Figure 9: Photokeratograph demonstrates irregular mires over incisions, implying nonhealed incisions. This photokeratograph was performed on the 1st postoperative day after radial keratotomy.

cein staining of the incisions for longer than 1 to 2 weeks following the procedure. Photokeratography was taken on each postoperative visit and irregular mires over the incisions (Fig 9) disappeared in all eyes at 1 to 2 months, suggesting appropriate wound healing without refractive instability. Diurnal variation of vision seemed to be the same as those seen after a primary radial keratotomy procedure, although specific data relating to this issue was not obtained in this study. Glare was not observed to be a complication of this procedure; in fact, many patients reported a decrease in glare following the procedures.

Microperforations, not requiring sutures, were observed in two eyes and required no further intervention. Microperforation during this procedure was identified immediately by a slight outrushing of aqueous fluid; the knife was withdrawn immediately and either reset to a slightly more shallow depth or the procedure continued on other incisions. In both instances, the microperforation occurred on the most temporal incision indicating the need for caution on this particular incision. I think the improved visualization possible during this procedure leads to fewer complications and less morbidity with the complications that occur. Unintended extension of the incision into the optical zone towards the visual axis and/or unintended deviation of the incision from the original location did not occur in any of these cases.

DISCUSSION

Given the inherent unpredictability of radial keratotomy, it is not surprising that reoperations have been performed on many eyes. Reoperation rates reported in various studies include: PERK, 14%;17 Hofmann, 4.5%;18 Franks, 23%;19 Sawelson and Marks, 17%;20 and Villasenor, 14%;21 all of which compare favorably with the reoperation rate of 17% in this study. In general, these reoperations have added additional incisions rather than entering original incisions. Hofmann18 reported five eyes in which he deepened the original incisions and all eyes improved to an uncorrected visual acuity of 20/30 or better. Hofmann attributed these shallow incisions to the use of a single-edged diamond knife. Villasenor reported 36 eyes who underwent additional radial incisions after radial keratotomy and concluded that eyes with deep incisions had a minimal additional correction of their myopia (0.58 D mean) while eyes with shallow incisions obtained significantly greater correction (2.46 D mean). He also reported that, in a manner analogous to the original radial keratotomy, eight additional radial incisions have little more effect than four additional radial incisions.21 Sawelson and Marks thought that younger patients with higher amounts of myopia required reoperation more frequently and felt that a relationship to shallow incisions was more variable.20

One of the most serious consequences of radial keratotomy has been the problem of overcorrections. Salz and coauthors22 have advocated the use of four-incision radial keratotomy as the first of a two-step procedure for low and moderate amounts of myopia. If the patient remains undercorrected after the four-incision radial keratotomy, an additional four incisions may be added at a later time. The ability to obtain additional myopic correction at the slit-lamp microscope indicates that we can intentionally shift the average result of an eight-incision radial keratotomy to a slightly myopic effect and limit overcorrections. Eyes that remain undercorrected can have the second procedure at the slit-lamp microscope without the necessity of returning to the operating room. I now explain radial kerato-
tomography to my patients in terms of this two-step procedure, indicating a gross correction will be obtained in the operating room while fine adjustment will be accomplished by means of postoperative medications and possibly “tickles” of the incisions at the slit-lamp microscope.

An optimal surgical technique must have the capability of modification, should the original surgery be less effective than desired. This article clearly shows that the undercorrected postoperative radial keratotomy patient can be safely, effectively, and repeatedly corrected with reoperations performed at the slit-lamp microscope. The problems of corneal instability when additional incisions are placed for undercorrections has been reported by myself (International Society of Refractive Keratoplasty Annual Pre-Academy Meeting, October 28, 1989, New Orleans, La) and others although little published data exists. Thus, the morbidity of any reoperation may be properly questioned. While the data reported in this article do not absolutely eliminate the possibility of instability, they indicate that the procedure stabilizes. Moreover, this procedure supports, but does not prove, the theoretical concept that the effect of radial keratotomy is due to a wedge-shaped addition of tissue in the incision, thus flattening the cornea. If this is true, repeated opening of the incisions could create larger effects without the necessity for additional incisions.

Eyes number 4 and 5 illustrate this principle. This patient had high myopia which was beyond the range of radial keratotomy performed with a 3.0-mm zone. The initial results after the primary procedure showed an expected undercorrection. However, we were able to achieve an acceptable correction by opening each incision twice without additional cutting which we theorize built up additional wedge-shaped scar tissue in each incision.

I believe that these procedures represent an evolutionary advance in radial keratotomy, creating the possibility of a multi-stage operation with improved precision with respect to the final refractive result and decreased overall morbidity. Moreover, patient confidence and satisfaction are improved with the knowledge that the refractive result can be refined if the initial operation is undercorrected or if myopia increases in the future.

REFERENCES


