Conductive Keratoplasty to Correct Residual Hyperopia and Astigmatism after Cataract Surgery

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Abstract

Purpose: To present conductive keratoplasty (CK) as a new procedure to correct residual hyperopia and astigmatism after phacoemulsification surgery and to evaluate its predictability, safety and stability.

Methods: Fifteen eyes of 13 patients with preoperative hyperopia +0.75 to +3.00 D and or astigmatism -0.75 to -3.00 D were enrolled into the study and underwent CK treatment. At the 1st and 3rd month follow-ups, near and far uncorrected visual acuity (UCVA) and best corrected visual acuity (BCVA), refraction, and in 6th month contrast sensitivity was also considered.

Results: In six months follow-up uncorrected visual acuity far (UCVAF) 20/40 or better increased from 10 eyes preoperatively to 12 eyes postoperatively. Uncorrected visual acuity near (UCVAN) 20/40 or better increased significantly from no case to 8 eyes postoperatively. Mean manifest sphere (MS) preoperatively was 1.5 D (±0.75) which decreased to 0.05 D (±0.7) postoperatively. Mean manifest cylinder (MC) preoperatively was -1D (±0.8) which was decreased slightly to -0.8 D (±0.5). Manifest refractive spherical equivalent (MRSE) preoperatively was 1 D (±1) which decreased to -0.3 D (±0.83) postoperatively. There was one eye with loss of more than 2 lines of best corrected visual acuity far (BCVAF) and we had no case of 2 lines loss of best corrected visual acuity near (BCVAN) during six months follow-up. No significant change occurred during 3rd to 6th months follow-up.

Conclusion: CK appears to be safe, effective and stable for correcting low to moderate hyperopic after cataract surgery, but more predictable nomogram is needed to correct postoperative astigmatism.

Keywords: Conductive Keratoplasty, Phacoemulsification, Hyperopia, Astigmatism


Introduction

The development of thermal methods used for the shrinkage of peripheral corneal collagen fibers, and hence steepening of the central cornea has attracted many ophthalmologists in the past 100 years. In the 1980’s, Fyodorof proposed the use of the hot-wire thermal keratoplasty to cause thermal burns to 95% of the corneal thickness in hyperopic patients, but was abandoned later due to instability and low predictability.1-4 Later other methods such as non-contact5-9 and contact10-12 holmium:yttrium-aluminum-garnet laser thermal keratoplasty (H0:YAG) laser thermokeratoplasty (LTK) were introduced.

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Nonthermal methods have also been used for the correction of hyperopia such as excimer laser photorefractive keratotomy (PRK)\textsuperscript{13-18} and laser in situ keratomileusis (LASIK).\textsuperscript{20-25} Today, the latest thermal technique is conductive keratoplasty (CK),\textsuperscript{26} which is a non-laser method in which the electrical energy in the form of radiofrequency is used to correct mild to moderate hyperopia. In this method, a uniform distribution of heat around the keratoplastic tip causes the shrinkage of collagen fibers and forms a cylindrical foot-print scarring at the site of application. Producing a full circle of spots causes the cinching effect and formation of striae leads to central steepening of the cornea, and so a myopic shift is produced. After an uneventful cataract surgery, patients may encounter some degrees of hyperopia and/or astigmatism that necessitate the use of spectacles to correct their vision. In this prospective study we present six months results of CK surgery in such cases.

**Methods**

Fifteen eyes of 13 patients with mild to moderate hyperopia and/or astigmatism were enrolled in this study. Inclusion criteria were at least 6 months interval between cataract surgery and CK, hyperopia of 1.0 to 3.0 diopter (D) or astigmatism of -0.75 to -3.0 D. Exclusion criteria were a pachymetry below 560 µm in the 6.0 mm optical zone, presence of any corneal disease, glaucoma, retinal problems, and any systemic disease such as diabetes, collagen or vascular diseases. Patients unable to complete their follow-up exams for some reasons were also excluded.

**Clinical examinations**

Preoperatively, all patients had a complete eye examination including the measurement of the uncorrected visual acuity (UCVA) and best corrected visual acuity (BCVA) for far and near, refraction, slit lamp exam, intraocular pressure, and a fundus exam. Orbscan and contrast sensitivity tests were also performed. The patients were examined at the 1st day, 1st week, and 3 and 6 months after surgery. At the first day and first week, severity of pain, any infection and healing process of the corneal epithelial defect were taken into consideration. At the 1st, 3rd month follow-ups, near and far UCVA and BCVA, refraction, and in 6th month contrast sensitivity was also considered.

**Introduction to CK**

The Viewpoint CK system from refractec, Inc. (Figure 1) used in this study consists of the following parts: a console that produces RF energy, a disposable pen-shaped hand piece connected to the console via a wire, a foot pedal that turns the current on and off, and an electrically grounded speculum. The energy level is 0.6 W with a 0.6 second exposure time. The tip of the probe contains a disposable stainless metal needle with a diameter of 90 µm and length of 450 µm that transmits the RF electrical energy directly to the corneal stroma. The probe contains a proximal curvature of 45° and a distal angulation of 90° to easily access the eye over the eyebrows and nose.

**Figure 1.** The conductive keratoplasty (CK) system that consists of a marker, a keratoplasty hand piece and its tip, a pedal and an electrically grounded eyelid speculum. The console weighs 14 pounds.

**Surgical method**

Surgery was done under topical anesthesia by instilling 2 drops of tetracaine 0.5% eye drop with a 5-minute interval. In astigmatic patients, the corneal periphery was marked with an insulin needle tip at 6 and 12 o’clock at the slit lamp. Once the patient was under surgical microscope, a special earth connected speculum was used to keep the eye open. The patient was asked to stare at the light of the microscope and the optical center of the cornea was marked with the tip of the Sinskey hook and a 7.0 mm optical zone marker with 8 intersections which was soaked in Gentian violet.
Eight radial lines were drawn from the 7.0 mm optical zone to 6.0-8.0 mm away from it (Figures 2 and 3).

In the next step, the cornea was dried with a Weck-Cel sponge to avoid loss of energy to other areas. The surgeon placed the tip of the probe vertically on the marked areas and pressed it into the cornea until the proximal end reached the stopper. At this point, the pedal was pressed to deliver radiofrequency (350 kHz) energy to each spot with 0.6 W energy and 0.6 second duration. Hyperopic eyes were treated on the basis of the number of spots specified in the nomogram (Table 1). For example, (Figure 3) for correcting 1.00-1.62 D hyperopia we had to apply 8 spots in the 6 mm, and 8 spots in the 7 mm optical zones. For correcting 2.375 to 3.00 D, 32 spots were required; 8 spots in each of the 6, 7, and 8 mm optical zones, and an extra 8 spots between the spots applied in the 7 mm optical zone. After every spot, the tip of the probe was cleared from tissue debris with a Weck sponge. In astigmatic patients, the flat axis was determined from simulated keratometry (sim KR) readings on the anterior float orbscan map, and for every -0.75 D of astigmatism a pair of spots were applied on the 7 mm optical zone.

Postoperative medications
At the end of the surgery, a therapeutic contact lens was applied on the cornea and the patient was advised to apply chloramphenicol drops every 4 hours for 3 days, and artificial tears every 4 hours for 1 week.

Probability analysis
Data was grouped based on descriptive statistics methods. For the comparison between different time distances, the mixed model ANOVA test was used. Acuity data were entered in the LogMAR scale. Data analyses were done with the SPSS software version 11.5.

Results
Fifteen eyes of 13 patients with an average age of 64±11 (range, 42 to 80) years were enrolled in this study. Eight patients (67%) were men. Best and uncorrected near and far visual acuity test results measured before and after CK are summarized in Table 2. In terms of UCVAF, there was no considerable change between the values before and after surgery (P=0.816). UCVA near, however, demonstrated a significant improvement after surgery (P<0.0001) (Figure 4).
There was no significant change in BCVAF after surgery (P=0.556) but there was a statistically significant difference between the BCVAN values before and after surgery (P=0.020). Comparing the values of BCVAN measured before surgery and different intervals, there was only a significant difference at 6 months (P=0.039) (Figure 5).

Table 3 contains the mean manifest sphere (MS), mean manifest cylinder (MC), and mean manifest refractive spherical equivalent (MRSE) in the operated eyes at the same intervals. In terms of MS, there was a significant probability difference among various time intervals (P=0.001), and this difference was observed between the preoperative value and all the values at various time intervals measured after surgery (Figure 6). In MC, there was no significant change between the values measured before and after surgery (P=0.315). In terms of MRSE, a statistically significant change was observed between the values measured preoperatively and at different time intervals after surgery (P<0.0001) (Figure 7).
Table 2. Best and uncorrected near and far visual acuity test results measured before and after conductive keratoplasty (CK)

<table>
<thead>
<tr>
<th></th>
<th>Before Surgery</th>
<th>1st Week</th>
<th>1st Month</th>
<th>3rd Month</th>
<th>6th month</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCVAF1</td>
<td>10 (66.7%)</td>
<td>10 (66.7%)</td>
<td>11 (73.3%)</td>
<td>10 (83.3%)</td>
<td>12 (80%)</td>
</tr>
<tr>
<td>UCVAN2</td>
<td>None</td>
<td>10 (66.7%)</td>
<td>9 (60%)</td>
<td>7 (58.3%)</td>
<td>8 (53.3%)</td>
</tr>
<tr>
<td>BCVAF3</td>
<td>15 (100%)</td>
<td>14 (93.3%)</td>
<td>14 (93.3%)</td>
<td>12 (100%)</td>
<td>14 (93.3%)</td>
</tr>
<tr>
<td>BCVAN4</td>
<td>14 (93.3%)</td>
<td>15 (100%)</td>
<td>15 (100%)</td>
<td>12 (100%)</td>
<td>15 (100%)</td>
</tr>
</tbody>
</table>

UCVAF: Number (percentage) of patients with an uncorrected visual activity for far vision of 20/40 or better
UCVAN: Number (percentage) of patients with an uncorrected visual activity for near vision of 20/40 or better
BCVAF: Number (percentage) of patients with a best-spectacle corrected visual activity for far vision of 20/40 or better
BCVAN: Number (percentage) of patients with a best-spectacle corrected visual activity for near vision of 20/40 or better

Table 3. The mean (±SD) values of MS, MC and MRSE before and after conductive keratoplasty (CK)

<table>
<thead>
<tr>
<th></th>
<th>Before Surgery</th>
<th>1st Week</th>
<th>1st Month</th>
<th>3rd Month</th>
<th>6th month</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS1</td>
<td>+1.5 (±0.75)</td>
<td>-0.15 (±0.8)</td>
<td>-0.01 (±0.7)</td>
<td>-0.3 (±0.7)</td>
<td>+0.05 (±0.7)</td>
</tr>
<tr>
<td>MC2</td>
<td>-1 (±0.8)</td>
<td>-0.8 (±1.25)</td>
<td>-1.2 (±0.7)</td>
<td>-1 (±0.8)</td>
<td>-0.8 (±0.5)</td>
</tr>
<tr>
<td>MRSE3</td>
<td>1 (±1)</td>
<td>-0.25 (±1)</td>
<td>-0.6 (±0.9)</td>
<td>-0.8 (±0.9)</td>
<td>-0.3 (±0.83)</td>
</tr>
</tbody>
</table>

MS: Mean manifest sphere in diopters
MC: Mean manifest cylinder in diopters
MRSE: Manifest refractive spherical equivalent in diopters

Discussion

After an uneventful cataract surgery, we may encounter some degrees of hyperopia that may be due to human errors (erroneous keratometric reading or axial measurement) or inaccuracy of intraocular lens power calculation formulas. There may also be some degrees of astigmatism which can be due to inappropriate placement of surgical incisions. In any case, these factors lead to a decrease in the patient UCVA and an increase in their dependency to spectacles.

The main goal of refractive surgery is improving the UCVA and this can be accomplished only if advantages outweigh disadvantages.27 There are different methods in correcting hyperopia after cataract surgery and all these methods aim at producing a steep central cornea. LASIK is one of the common methods, but this is not considered an appropriate method due to the higher age range of patients undergoing cataract surgery, the prevalence of dry eye and problems related to epithelial and corneal flap healing.

CK produces heat by passing electrical energy through the cornea and hence causes the shrinkage of collagen fibers and a cylindrical foot-print scar up to 80% of the depth of the cornea.28,29 In a study performed by Rojas and Manche, the videokeratographic optical zone was measured to be 31.1 mm² in CK and 24.6 mm² in hyperopic LASIK; a larger and smoother central steepening was produced in CK when compared to hyperopic LASIK.30

A new CK technique, named the light touch CK, is a minimal compression technique used instead of high compression in which the cornea is slightly compressed (about 0.5-1 mm) before energy is applied.31 The advantage of this technique is a smaller corneal dimple which is one-fifth or one-seventh of that in conventional CK. Fewer spots are required; 8 spots instead of the usual 16 or 24 spots, leaving enough space for performing the next CK surgery. In a study by McDonald et al, the light touch CK was compared with conventional CK in terms of refraction within ±1.0 D (85% vs. 63%), stable cylinder (90% vs. 71%), induced astigmatism under 1.0 D (6% vs. 17%), and induced
astigmatism more than 1.0 D (4% vs. 12%). However, no certain nomogram has been produced. A few studies have been performed on CK in correcting mild to moderate hyperopia, the most important is the one by McDonald et al and agarwal. To our knowledge, there are no peer reviewed articles on the correction of hyperopia and astigmatism after phacoemulsification surgery, and the present study may be first of the kind.

In this study, the visual results 6 months after CK showed that 80% of the patients had a UCVA far equal to $20/40$ or better; a result quite similar to the 85% reported by FDA and 93% by McDonald et al. About 53% of the patients acquired a UCVA near of $20/40$ or better. In correcting hyperopia, the predictability was shown to be good, although the sample population was small. The mean MS of 1.5 D reduced to 0.5 D after surgery. The mean spherical equivalent was within ±1.0 D in 85.7%, compared to 93% in McDonald’s study and an FDA target of 75%. In 35.7% of patients, the MRSE was within ±0.5 D, compared to 46% in McDonald’s study and an FDA target of 50%.

In terms of astigmatism, degrees of overcorrection were seen because there is no clear nomogram for the correction of cylinder error. The mean MC reduced from -1.0 D to -0.8 D after surgery, indicating that the nomogram requires further improvement.

In terms of stability, the mean MS was near emmetropia during the first 3 months after surgery. Between 3 and 6 months, some degree of regression was seen, which seemed to stabilize by the 6th postoperative month. The change in mean MRSE between 3 and 6 months after surgery was 0.5 D.

In terms of safety, the BCVAF values of $20/40$ or better did not change in 93% of patients, as it was observed that was no significant change when compared to before surgery but there was one eye with loss of more than 2 lines of it which could be due to irregular astigmatism or mild decentration of spots. BCVAN value of $20/40$ or better increased from 93.3% to 100% after surgery that shows no significant change and we had no case of 2 lines loss of best corrected visual acuity for near vision (BCVAN) during six months follow-up. The floating of the cornea was not serious so as to cause a reduction in the depth of the anterior chamber and an increase in the pressure of the eye.

**Conclusion**

In conclusion, this non-laser method is capable of correcting hyperopic cases after phacoemulsification surgery, because it leaves the central cornea untouched and there are no flap related complications. However, there is an obvious need for studying the light touch technique and developing new nomograms for correcting astigmatism.

**References**