Architectural Analysis of Clear Corneal Incision Techniques in Cataract Surgery Using Fourier-Domain OCT

Anderson Teixeira, MD, PhD; Camila Salaroli, MD; Flavio Rezende Filho, MD, PhD; Francisco Teixeira Pinto, MD; Nonato Souza; Benedito Antonio Sousa, MD; Norma Allemann, MD, PhD

BACKGROUND AND OBJECTIVE: To compare the architecture of single plane self-sealing clear corneal incision (SP-CCI) and shallow grooved self-sealing clear corneal incision (SG-CCI) after cataract surgery using Fourier-domain optical coherence tomography (FD-OCT).

PATIENTS AND METHODS: An FD-OCT system with a corneal adaptor module was used to image the corneal incisions in radial sections in 44 eyes. A line scan pattern was used to measure the corneal incision, positioning the caliper mark perpendicular to the limbus. Measurements were performed immediately after cataract surgery and at postoperative days 1, 7, and 30. Incisions were analyzed regarding length, location, angle, architecture, and anatomic imperfections.

RESULTS: All incisions were located superiorly (temporal, 24 eyes; nasal, 20 eyes). The mean SG-CCI length (20 eyes) was 1.79 ± 0.31 mm (range: 0.93–2.64 mm) and the mean incision angle was 37 ± 7 degrees (range: 27–52 degrees) \( (P < .05) \). Anatomic imperfections were observed at postoperative day 1 in 19 eyes for SP-CCI and 14 eyes for SG-CCI. No patient presented endophthalmitis during 30 days of follow-up.

CONCLUSION: Epithelial imperfection at the corneal incision site was observed in more than 36% of the wounds (36% in SP-CCI and 45% in SG-CCI) at postoperative day 1 with spontaneous resolution. SG-CCI had the greatest length and lowest angle of corneal incision. Reduced incision length and inappropriate construction may determine risk factors for wound architectural imperfections. Further studies including more patients with an architectural analysis of clear corneal incisions are needed to confirm these preliminary results.

INTRODUCTION

Clear corneal incision (CCI) in cataract surgery is accepted worldwide. It allows rapid visual rehabilitation and involves less induced corneal astigmatism, less bleeding during surgery, higher structural stability of the anterior chamber, and ease in construction.\(^1\) On the other hand, some studies suggest that CCI may be associated with an increased risk of postoperative endophthalmitis\(^4\) and self-sealing behavior of the wound is an important barrier against intraocular infection. CCI can be performed by either single plane self-sealing construction or two plane self-sealing construction (shallow grooved self-sealing construction). The difference between the techniques depends on the corneal construction tunnel to generate a self-sealing valve and safety postoperative workout.\(^8\)

Anterior segment optical coherence tomography (AS-OCT) is a non-contact method used to examine the architecture features of CCI in vivo after cataract surgery such as epithelial and endothelial gaping, endothelial misalignment, Descemet's membrane detachment, distance from the limbus, and length, shape, angle, and thickness of the CCI.\(^3\) Spectral-domain OCT (SD-OCT) has good quality resolution and acquisition is faster, allowing adequate screening for postoperative follow-up to analyze the corneal incision.

The objective of this study was to demonstrate the architectural features and the dimensions of the corneal wound after cataract surgery using SD-OCT and to correlate them to surgical outcomes. This study provided accurate measurement of the wound in vivo using high-resolution, clearly visible SD-OCT images of the cornea right after the phacoemulsification procedure without significant motion error, enabling analysis of the differences of the incision techniques.

PATIENTS AND METHODS

Study participants were recruited from clinical practices (AT, FTP, and CS) according to a prospective study protocol approved by the institutional review board. Informed consent was obtained and documented for every participant. The study adhered to the tenets of the Declaration of Helsinki. Forty-four eyes of 30 patients with cataract and no other ocular diseases were enrolled in the study.

Randomly selected eyes underwent cataract surgery with the clear corneal incision performed using either technique. Patients were divided in two groups: 24 eyes received single plane self-sealing clear corneal incision (SP-CCI) construction and 20 eyes received shallow grooved clear corneal incision (SG-CCI) construction.

All phacoemulsification surgeries were performed by the same surgeon (AT) and CCI was performed superonasally in the left eye or superotemporally in the right eye. The incisions were made with a 2.75-mm metal keratome (Angiotech Inc., Reading, PA) and phacoemulsification surgery was performed using the Alcon Legacy system (Alcon Laboratories, Inc., Fort Worth, TX) under topical anesthesia with less than 0.5 minute of ultrasound (burst mode). Lens cortex was removed by automated irrigation and aspiration using a bimanual set-up. A foldable acrylic intraocular lens (Akreos AO; Bausch & Lomb, St. Louis, MO) was injected into the capsular bag using a disposable implantation system, without any incision tunnel enlargement. Phacoemulsification and side-port incisions were sealed with stromal hydration using balanced salt solution. The eyes were filled with balanced salt solution to normal pressure on palpation without leaking.

A Fourier-domain OCT system (RTVue; Optovue Inc., Fremont, CA) with a corneal adaptor module was used to image the CCI immediately after the surgery and at postoperative days 1, 7, and 30 to evaluate the incision morphology. A line scan pattern was used to measure the corneal incisions, positioning the caliper mark perpendicular to the limbus. On OCT, radial scans were performed at the corneal incision site to analyze the following parameters: curvilinear length (total length measured by six points between the internal and external wound openings, Figure 1B), linear length (line between the internal and external wound openings, Figure 1A), angle between the corneal surface tangent, architectural deformation, and external depth of the incision at each of the three stages of the wound.

SAS version 9.1 programming language (SAS Institute, Inc., Cary, NC) was used for all analyses. The data were analyzed by linear and curve length, shallow groove, incision angle, and epithelial and endothelial gaping. The paired \(t\) test was used to compare the different incision techniques and analysis of variance tested across days. A \(P\) value of less than .05 was considered significant for all tests.
RESULTS

Thirty participants (44 eyes) were enrolled and completed the study: 18 men and 12 women. Mean age was 68 ± 12 years (range: 52 to 82 years). No intraoperative complication or incision leakage was seen in any of the participants. During 30 days of follow-up, there were no reports of hypotony, shallow chamber, or endophthalmitis.

The average curvilinear length was 1.64 ± 0.22 mm (range: 1.25 to 2.36 mm) for SP-CCI and 1.79 ± 0.31 mm (range: 0.93 to 2.64 mm) for SG-CCI, which was statistically significant (P = .04). The average linear length of the incision from external to internal opening was 1.61 ± 0.24 mm (range: 1.25 to 2.28 mm) for SP-CCI and 1.62 ± 0.27 mm (range: 0.89 to 2.40 mm) for SG-CCI, which was not statistically significant (P = .92). The average angle of the incision relative to the tangent plane to the corneal surface was 38 ± 5 degrees (range: 27 to 52 degrees) for SP-CCI and 37 ± 7 degrees (range: 21 to 52 degrees) for SP-CCI; there were no significant differences between groups (P = .12). The shallow grooved average was 0.24 ± 0.61 mm (range: 0.14 to 0.40 mm). Tables 1 and 2 list all postoperative average measurements for both groups with the analysis of variance between days.

Changes on the Epithelial Side of the Wound

Epithelial gaping was observed in both groups. It was noted in 21% of the participants on the day of surgery and 8% on postoperative day 1 for SP-CCI and 47% and 10%, respectively, for SG-CCI. No epithelial changes were observed after postoperative day 1 in both groups. The average of epithelial changes was 0.11 ± 0.04 mm (range: 0.05 to 0.15 mm) for SP-CCI and 0.13 ± 0.1 mm (range: 0.02 to 0.33 mm) for SG-CCI, with no significant differences between groups (P = .66).

Changes on the Endothelium Side of the Wound

Endothelium gaping was observed in both groups. For SP-CCI, it was noted in 79% of the participants on the day of surgery, in 42% on postoperative day
Three patients had endothelial gaping at postoperative day 30 (2 for SP-CCI and 1 for SG-CCI). The average of endothelial gaping was $0.13 \pm 0.06$ mm (range: 0.04 to 0.28 mm) for SP-CCI and $0.13 \pm 0.05$ mm (range: 0.05 to 0.22 mm) for SG-CCI, with no significant differences between groups ($P = .82$). Descemet’s detachment and endothelial misalignment were observed in both groups (Table 3) with a complete resolution at 30 days postoperatively.

### TABLE 3

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SP-CCI</th>
<th>SG-CCI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descemet’s detachment</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Endothelial misalignment</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Loss of coaptation</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Endothelium gaping</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td>Epithelium gaping</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

FD-OCT = Fourier-domain optical coherence tomography; SP-CCI = single plane self-sealing clear corneal incision; SG-CCI = shallow grooved self-sealing clear corneal incision.

### DISCUSSION

CCIs are classified by their architecture as being either single plane when there is no groove at the external edge of the incision, shallow grooved when the initial groove is less than 400 microns, and deeply grooved when it is deeper than 400 microns. There are articles about CCI that have studied the integrity and healing of the architecture at the incision site, and wounds greater than 2.0 mm in length and 3.0 to 3.5 mm in width demonstrated sufficient self-sealing. In our series, there was a discrepancy comparing linear and curve length measurements, and our results dem-
onstrate that average linear measurements were smaller than 2.00 mm in both groups and that the SG-CCI group had a longer length. The shortfall might be explained by the stretching of the cornea under the force of the advancing metal blade.\textsuperscript{3} SG-CCI had a lower incidence of endothelial gaping comparing to SP-CCI, but both groups had patients with endothelial gaping still present after postoperative day 30 (1 eye for SG-CCI and 2 eyes for SP-CCI). Epithelial defects were more frequently observed for SG-CCI, with resolution between postoperative days 1 and 7. Independent of the technique used for the corneal incision, all eyes enrolled in the current study had a proper self-sealing CCI. In the literature, some authors advocate the use of SG-CCI and others suggest that SP-CCI is safe in most cases.\textsuperscript{3,18-20}

The angle of the incision is an important factor to maintain the integrity and sealing properties of the wound. Small angles have been shown to be more effective at creating a self-sealing condition.\textsuperscript{3,21} In the current study, the angle appeared to be shallow enough to create sealing (average angle = 39 degrees for SP-CCI and 37 degrees for SG-CCI, $P = .48$) for all eyes in both groups.

We observed that there was external wound gaping in 21\% of the OCT images on the day of surgery for SP-CCI, which decreased to 8\% on postoperative day 1 and was not observed at days 7 and 30. For SG-CCI, external wound gaping was observed in 47\% on the day of surgery, 10\% on postoperative day 1, and was not observed during the following examinations. External gaps can be found in CCI with a fast resolution\textsuperscript{4,10,21,22} and can be associated with intraocular pressure fluctuation and stromal hydration.\textsuperscript{4,10,14}

Endothelial wound gaping was observed in both groups, with a higher incidence for SP-CCI ($P = .82$). In the literature, the incidence of endothelial wound gaping varies between 25\% and 70\%, depending on the postoperative day.\textsuperscript{4,10,14,21,22} Some authors suggested possible explanations for endothelial wound gaping, such as phacoemulsification instrument sizing or excessive ultrasound power, corneal stromal edema, and endothelial damage.\textsuperscript{13,14,23} Other authors added intraocular pressure fluctuation as a factor.\textsuperscript{4,21}
Corneal incisions related to cataract surgery in both groups imaged with SD-OCT presented internal and external gaps in the immediate postoperative period with a spontaneous resolution. Both techniques seemed to be safe regarding self-sealing, but SG-CCI demonstrated a longer incision length. SD-OCT imaging allowed immediate postoperative non-contact evaluation of patients undergoing cataract surgery and provided high-resolution measurements for evaluating the incision's morphology. This information may be used to select corneal incision instruments and techniques to diminish the risk of gaping, which can be related to visual rehabilitation and to an increased risk of postoperative complications.

REFERENCES