



Stabilization Period for Central Corneal Thickness, Anterior Chamber Depth, and Iridocorneal Angle Parameters After Deep Anterior Lamellar Keratoplasty in Keratoconus Patients

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Abstract

Objectives: The purpose of this study was to assess the stabilization of anatomical outcomes of central corneal thickness (CCT), anterior chamber depth (ACD), and iridocorneal angle (ICA) in keratoconus-affected eyes after deep anterior lamellar keratoplasty (DALK).

Methods: Keratoconus patients who underwent DALK surgery at Beyoğlu Eye Training and Research Hospital between January 2013 and May 2015 were retrospectively analyzed. Patients with data recorded preoperatively, 1 month postoperatively, and 1, 6, and 12 months post suture removal, including refractive status, best corrected visual acuity (BCVA), CCT, ACD, and ICA parameters were included in the study. The CCT, ACD, and ICA parameters were assessed with anterior segment optical coherence tomography.

Results: A total of 42 eyes of 37 patients with a mean age of 30.5 ± 10.5 years were analyzed. The mean preoperative and post-suture removal 12th-month BCVA was 1.41 ± 0.43 logarithm of minimal angle of resolution (logMAR), and 0.34 ± 0.1 logMAR, respectively ($p < 0.001$). The ACD (11%; $p < 0.001$) and ICA (3%; $p = 0.009$) values significantly increased, whereas the CCT (2%; $p = 0.008$) decreased after suture removal. The ICA and CCT values demonstrated stability 1 month after suture removal, and the ACD was stable 6 months after suture removal.

Conclusion: Our study results indicated that the ICA and CCT stabilized 1 month post suture removal and the ACD stabilized 6 months after suture removal. A waiting period of at least 6 months after suture removal is recommended before any post-DALK refractive surgery.

Keywords: Anterior chamber depth, deep anterior lamellar keratoplasty, iridocorneal angle, keratoconus

Introduction

Keratoconus is the most common form of bilateral corneal ectasia. Thinning of the corneal stroma leads to the cornea gradually taking on a conical shape, which can cause irregular astigmatism, myopia, and protrusion, and mild to marked

vision impairment (1). Management of keratoconus varies depending on the progression of the disease (1,2).

Corneal collagen cross-linking is a well-established first-line therapy to prevent keratoconus progression and potentially also provide some improvement in visual acuity (VA) (3). Early cases of keratoconus can be managed with eyeglasses,

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and contact lenses or intracorneal ring implants can be used for mild to moderate cases. Corneal transplantation is the final option for visual rehabilitation in patients who cannot tolerate or do not adequately benefit from more conservative alternatives (1,3). Deep anterior lamellar keratoplasty (DALK) is a lamellar corneal graft technique. The donor cornea is transplanted leaving the endothelium and the Descemet's membrane (DM) intact, which reduces the incidence of preoperative and postoperative complications and graft rejection (4). DALK is now preferred to penetrating keratoplasty (PK) in patients with a healthy endothelium (4,5).

DALK surgery is a partial-thickness procedure and the wound is stronger than that created with PK. Nonetheless, sometimes new problems may arise, such as ocular surface disease, glaucoma, suture-related problems, refraction change, or rejection. High refractive errors are frequently seen after keratoplasty, and may change in the postoperative period (6). Changes in refractive errors over time after DALK largely occur for 2 reasons. The primary cause of refractive instability is the avascular vertical wound between the donor and the recipient, which is extremely slow to heal and is never as strong as the virgin tissue. This can lead to variations in the wound architecture during the healing process (7,8). Second, progressive changes in the graft tissue, and even recurrence of keratoconus, have been reported after DALK (9,10).

The purpose of this study was to assess the stabilization of the anatomical outcomes of CCT, ACD, and ICA of keratoconus-affected eyes following DALK surgery. To the best of our knowledge, this article is the first to report ACD changes after DALK suture removal.

Methods

This study was conducted in accordance with the Declaration of Helsinki and with the approval of the ethics committee of Gaziantep University. All of the participants provided written, informed consent. The files of keratoconus patients who underwent DALK surgery at Beyoğlu Eye Training and Research Hospital between January 2013 and May 2015 were retrospectively examined. Additional ocular disease affecting VA, the presence of any corneal scar extending to the DM, a history of acute hydrops, concurrent or pre-DALK ocular surgery, missing data for target parameters, or unremoved sutures were exclusion criteria.

A routine ophthalmological examination, including refraction testing, intraocular pressure (IOP) measurement, and anterior segment and fundus examinations, was performed for all of the eyes included in the study. Keratometry and corneal tomography examinations were also performed, and the diagnosis of keratoconus was confirmed based on clinical refraction, slit lamp, keratometry, and corneal tomography results. DALK surgery was performed for patients with advanced keratoconus and a viable endothelium.

All of the surgeries were performed under general anesthesia by a single surgeon using the big-bubble technique described by Anwar. Big bubble development was observed in all of the study patients. The diameter of the trepan was determined by measuring the cone width with a caliper (average: 7.50 mm). The donor tissue was prepared using punch blades to be 0.25 larger than the recipient bed diameter. The endothelium was removed from the donor cornea using 0.06% trypan blue. The endothelium-free donor cornea was then sutured with 10/0 nylon on the recipient cornea. Single row continuous corneal suturing was used in all cases.

After the surgery, topical moxifloxacin 0.5%, artificial tears (polyvinyl alcohol and povidone), and dexamethasone 0.1% were administered 6 times a day. The use of eye drops was gradually tapered over 6 months. The sutures were removed between 6 months and 12 months after the surgery.

The CCT, ICA, and ACD parameters measured at the final preoperative visit, 1 month postoperatively, and 1, 6, and 12 months post suture removal, as well as the best corrected visual acuity (BCVA) and manifest spherical equivalent values at the final preoperative and postoperative visits, were recorded. The manifest astigmatism and spherical equivalent values were determined using subjective refraction procedures. The ICA, ACD, and CCT results were obtained using anterior segment optical coherence tomography (AS-OCT) (Visante; Carl Zeiss AG, Oberkochen, Germany). These tests were performed by 1 experienced technician to reduce variability.

Statistical Analysis

The mean and SD values of the study data were used as descriptive statistics. The normality of the distribution of the variables was examined using the Kolmogorov-Smirnov test. A dependent sample t-test and the Wilcoxon test were used in the analysis of quantitative data. IBM SPSS Statistics for Windows, Version 21.0 software (IBM Corp., Armonk, NY, USA) was used to perform the analyses. A p value of <0.05 was considered significant.

Results

In total, 42 eyes of 37 patients were included in the study. Twenty (54.06%) of the patients were female and 17 (45.94%) were male. The mean age of the patients was 30.5 ± 10.5 years (range: 14–56 years).

The preoperative and postoperative visual and refractive changes are shown in Table 1. T-tests of dependent groups indicated that the mean postoperative BCVA was statistically significantly higher than the preoperative value ($p < 0.001$).

The CCT, ICA, and ACD values measured at the target points are displayed in Table 2. A significant decrease in mean ACD (14%; $p < 0.001$) and ICA (4%; $p = 0.004$) values was seen from the last preoperative visit to the first-month postoperative visit. There was a significant increase from the

Table 1. Visual and refractive results before and after surgery

BCVA	Mean±SD
Final preoperative visit	1.41±0.43 logMAR *
Final postoperative visit	0.34±0.17 logMAR *
Final postoperative visit astigmatism	3.8±2.3 D
Final postoperative visit spherical equivalent	-2.7±3.2 D

*p<0.001 (paired samples t-test); BCVA: Best corrected visual acuity; D: Diopter; logMAR: Logarithm of the minimum angle of resolution.

1-month postoperative visit to the 1-month post-suture removal visit in ACD (11%; p<0.001) and ICA (3%; p=0.009) values. The mean ACD value increased significantly between the first-month and the sixth-month post-suture removal measurements (4%; p=0.004), whereas no significant change was observed in the ICA in the same period (p>0.05). There was no significant change in the ACD or ICA between the sixth month and 1 year post suture removal (p>0.05).

The CCT measurement increased from the last preoperative visit to the first-month postoperative visit (46%; p<0.001) and decreased from the first-month postoperative visit to the post-suture removal first-month visit (2%, p=0.008). No significant difference was detected after the first-month post-suture removal visit (p>0.05).

Discussion

The purpose of this study was to determine the stability of CCT, ACD, and ICA parameters in eyes with keratoconus after DALK.

The incidence of glaucoma has been reported to be between 10% and 53% after PK and 0% and 17% after DALK. A high IOP may be caused by long-term steroid use, changes in ICA architecture, changes in trabecular architecture caused by intraoperative and postoperative mechanical forces, or inflammation (13). ICA measurements may reflect mechanical angular distortion. In a study evaluating ICA change at 6 months after PK, a slight, non-significant decrease was re-

ported (14). Our results indicated that the mean ICA value was slightly, but significantly, lower at 1 month after DALK. The ICA was found to be slightly, but significantly, higher after suture removal. These differences were probably a result of tension changes due to the sutures. The mean ICA was found to be stable at the first month after suture removal. We observed statistically significant ICA changes, but they were small and the clinical significance should be further evaluated.

Significant increases in BCVA in keratoconus patients for 3 to 6 months after DALK surgery have been reported, however, this is primarily a result of the reduction in irregular astigmatism (9,12). In this study, consistent with the literature, we found a significant improvement in BCVA at the final visit compared with measurements taken before surgery.

The ACD in keratoconus patients is expected to be high due to ectasia. Ort et al. (14) analyzed PK results in keratoconus patients and reported that the ACD values in the preoperative and postoperative sixth-month visits were 3.92±0.47 mm and 3.01±0.55 mm, respectively (23% decrease). However, the evaluation was made before removal of the sutures. In another study of PK in keratoconus patients, the ACD values at preoperative and postoperative 2-year visits were 3.72±0.43 mm and 3.47±0.33 mm, respectively (7% decrease). In the same study, it was reported that the sutures were removed at the postoperative 12th month, but the effect of suture removal on ACD could not be evaluated because no post-PK value was given (15). In our study, the ACD value determined with AS-OCT decreased from 3.78±0.52 mm to 3.27±0.49 mm (14% decrease) in the first month after DALK, which is consistent with the literature. After the suture removal, it increased to 3.62±0.54 mm (11% increase) in the first month and 3.77±0.48 mm (4% increase) in the sixth month, and stabilized afterwards. It is not surprising that the ACD increased with suture removal, but the continuation of this change shows that the adaptation of the cornea takes more than 1 month.

Corneal thinning is a feature of keratoconus, and an in-

Table 2. CCT, ICA, and ACD values measured using AS-OCT

AS-OCT	Final preoperative visit	P _{diff}	Postoperative 1 st month	P _{diff}	Post-suture removal 1 st month	P _{diff}	Post-suture removal 6 th month	P _{diff}	Post-suture removal 12 th month
ACD (mm)	3.78±0.52	<0.001 t	3.27±0.49	<0.001 t	3.62±0.54	0.008 w	3.77±0.48	0.214 w	3.81±0.58
CCT (µm)	354±80	<0.001 t	517±66	0.008 w	506±57	0.141 w	503±58	1.000 w	503±55
ICA (%)	44.9±10	0.004 w	43.1±8.8	0.009 w	44.3±8.2	0.760 w	44.7±7.9	0.571 w	43.7±8.0

Pdiff: Probability of intragroup change by chance; t: paired t-test; w: Wilcoxon test; ACD: Anterior chamber depth; AS-OCT: Anterior segment optical coherence tomography; CCT: Central corneal thickness; ICA: Iridocorneal angle.

crease in CCT after corneal transplantation surgery is expected. An increased CCT reported in long-term follow-up of PK patients has been attributed to progressive endothelial loss (16). In our study, the CCT values were 334 ± 50 μm , 532 ± 62 μm , and 517 ± 58 μm at the preoperative visit, 1 month post-DALK, and 1 month post-suture removal visit, respectively, and stabilized afterwards. A CCT increase after surgery is consistent with results in the literature. There was also a slight difference between the first month after surgery and the first month after suture removal. These data seem to indicate that functional attachment of the endothelium and lamellar graft requires more than 1 month.

Although spherical equivalent, mean keratometry, and astigmatism values decrease after DALK surgery in keratoconus patients, it is not uncommon to encounter a high refractive error after surgery. It has been reported that myopic shift formation continued for 1 to 6 months after suture removal, but the spherical equivalent value remained stable at 6 to 24 months. Refractive astigmatism and mean keratometry values have been reported to be stable at 1 to 24 months after suture removal (9,12).

Non-surgical, conservative methods, such as eyeglasses and contact lenses, are the initial means used to rehabilitate post-DALK refractive errors. When these modalities are not adequate, corneal and intraocular surgical correction options are the treatment of choice (11,17).

Several corneal surgery options are available, such as laser-assisted surgery and manual keratotomies (11,18-21). The prerequisites for all surgeries are a minimum interval of 6 months and a stabilized refractive state after suture removal. Improved uncorrected VA and decreased refractive error are standard (11,18,20). In a study reporting the results of treatment with LASIK for refractive error after DALK suture removal, it was reported that the mean keratometry, spherical equivalent, and uncorrected VA did not change between 1 month after LASIK and the final visit (mean: 11 months). The authors also reported that 67% of the patients had a subjective refractive error within ± 1.0 diopters (D) and that 92% had within ± 2.0 D (11). In our study, we observed that the CCT, which may be important for corneal refractive surgery, did not change beyond 1 month after suture removal.

Intraocular surgical options include the implantation of a variety of lenses. The prerequisites for surgery are similar to those for corneal refractive surgery. Improved uncorrected VA and decreased refractive error have regularly been reported (22-24). Newer generation IOL calculation formulas, such as the Haigis and Holladay formulas, require ACD measurement. Formulas including the ACD parameter are recommended for eyes with abnormal anterior segment anatomy (25). Patients who have undergone corneal transplantation may be included in this group, but since the ACD

may change in the postoperative period, determination of the optimal timing for intraocular surgery is important for a satisfactory outcome. In addition, in a study in which iris claw lenses were implanted after DALK, there was a prerequisite that the ACD should be greater than 3.2 mm (23). In our study, we found that the ACD had stabilized 6 months after suture removal. To the best of our knowledge, this article is the first to report this finding, which may be important for the success of intraocular refractive surgery.

Limitations of our study include a small patient group; follow-up points limited to the final preoperative visit, 1 month post DALK, and 1, 6, and 12 months after suture removal; and the fact that keratometry, manifest refraction, and IOP measurements were not included.

Conclusion

Although a significant change in the corneal and anterior chamber parameters occurs after DALK surgery, stability was attained after suture removal. According to our study results, the CCT and ICA parameters were stable between the 1st and 12th months, and the ACD was stable between 6 and 12 months after suture removal.

Disclosures

Ethics Committee Approval: Gaziantep University Clinical Research Ethics Committee, 2018/300, 05.12.2018.

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Conflict of Interest: None declared.

Authorship Contributions: Involved in design and conduct of the study (GKD); preparation and review of the study (GKD, MO); data collection (GKD); and statistical analysis (MO).

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