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Superficial Keratectomy and Conjunctival Advancement Hood Flap (SKCAHF) for the Management of Bullous Keratopathy: Validation in Dogs With Spontaneous Disease

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Abstract

Purpose—To evaluate the efficacy of superficial keratectomy and conjunctival advancement hood flap (SKCAHF) for the treatment of bullous keratopathy in canine patients.

Methods—Nine dogs (12 eyes) diagnosed with progressive corneal edema underwent superficial keratectomy followed by placement of conjunctival advancement hood flaps. The canine patients were examined pre- and postoperatively using in vivo confocal microscopy, ultrasonic pachymetry (USP), and Fourier-domain optical coherence tomography (FD-OCT). All owners responded to a survey regarding treatment outcomes.

Results—Mean central corneal thickness (CCT) as measured by FD-OCT was 1163 ± 290 μm preoperatively and significantly decreased postoperatively to 795 ± 197 μm ($P = 0.001$), 869 ± 190 μm ($P = 0.005$), and 969 ± 162 μm ($P = 0.033$) at median postoperative evaluations occurring at 2.2, 6.8, and 12.3 months, respectively. Owners reported significant improvement ($P < 0.05$) in vision and corneal cloudiness at 6.8 and 12.3 months postoperatively. The percentage of cornea covered by the conjunctival flap was correlated ($P = 0.0159$) with a reduction in CCT by USP at 12.3 months postoperatively. All canine patients were comfortable pre- and postoperatively.

Conclusions—SKCAHF results in a reduction of corneal thickness in canine patients with bullous keratopathy. The increase in corneal thickness over time, after performing SKCAHF, is likely because of progressive endothelial decompensation. This surgery is a potentially effective intervention for progressive corneal edema in dogs that may have value in treatment of human patients with bullous keratopathy.

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Keywords

bullous keratopathy; corneal edema; fuchs endothelial corneal dystrophy; canine corneal endothelial dystrophy; conjunctival flap

Treatment options for bullous keratopathy depend on the severity of the disease. Patients with good visual potential most commonly undergo corneal transplantation procedures including Descemet stripping automated endothelial keratoplasty, Descemet membrane endothelial keratoplasty, or penetrating keratoplasty.[1–3] In patients with limited visual potential, the aim is to relieve ocular discomfort while optimizing cosmesis and minimizing surgical management. Nonsurgical treatments include hypertonic saline eye drops and ointment[4] and bandage contact lenses.[5] However, surgical techniques including collagen cross-linking,[6] anterior stromal puncture,[7] mid-infrared laser pancorneal coagulation,[8] thermal cautery of the anterior corneal stroma (Salleras procedure),[9] conjunctival flaps,[10–12] amniotic membrane transplantation,[13,14] phototherapeutic keratectomy,[15,16] and enucleation or evisceration are often required to minimize pain.

Corneal endothelial dysfunction with secondary bullous keratopathy also occurs in canine patients because of similar causes as humans such as corneal endothelial dystrophy (CED),[17–19] intraocular surgical procedures,[20] glaucoma,[21] and diabetes mellitus.[22] The use of conjunctival flaps for the treatment of canine bullous keratopathy has been previously reported, but outcomes in comfort, vision, and corneal thickness had not been quantitatively assessed.[23,24] We used Fourier-domain optical coherence tomography (FD-OCT) and in vivo confocal microscopy (IVCM) to perform detailed evaluation of canine corneal endothelial dysfunction and to objectively evaluate the efficacy, safety, and owner satisfaction of a superficial keratectomy and conjunctival advancement hood flap (SKCAHF) in the treatment of canine bullous keratopathy.

Materials and Methods

This study was approved by the Institutional Animal Care and Use Committee of the University of California–Davis (#17680) and performed according to the Association for Research in Vision and Ophthalmology resolution on the use of animals in research. Informed consent was obtained for patients with progressive corneal edema caused by corneal endothelial dysfunction at the Animal Eye Center in Rocklin, CA, and the University of California–Davis Veterinary Medical Teaching Hospital between July and December 2013. Corneal edema was described based on the percentage of cornea affected: focal (<40% affected), extensive (40%–80% affected), and diffuse (.80% affected). Inclusion criteria were corneal edema of any extent with progression despite treatment with topical 5% sodium chloride (NaCl) ophthalmic ointment q 4 to 8 hours as observed by the clinician based on 2 or more examinations before surgery. Exclusion criteria were the presence of other conditions that may render the eye to have poor visual potential even with improvement of corneal edema such as advanced stages of cataracts and retinal degeneration; uveitis, glaucoma, or lens instability; history of previous intraocular surgery; and high anesthetic risks (grade III/IV or higher on ASA Physical Status Classification System).

Before and at median of 2.2, 6.8, and 12.3 months after surgery, all eyes underwent complete ophthalmic examination, Schirmer tear test-1 (STT-1), applanation tonometry, fluorescein staining, ultrasonic pachymetry (USP, Pachette 3; DGH Technology, Inc, Exton, PA), FD-OCT (RTVue 100; Optovue Inc, Fremont, CA), IVCM (ConfoScan 4; Nidek Technologies, Gamagori, Japan), and digital slit-lamp biomicroscopy (Haag-Streit BQ900 with IM900 module; Haag-Streit AG, Koeniz, Switzerland). Intravenous sedation was given as needed for imaging.

Surgical Procedure

All procedures were performed under general anesthesia using an operating microscope. Peripheral corneal sector(s) most severely affected with corneal edema were determined using USP measurements and ophthalmic examination findings and selected for the lamellar keratectomy with the intent to spare the central cornea and provide the clearest visual axis possible. The shape and exact locations of conjunctival flaps differed among cases (Fig. 1). Case 1 was an exception, wherein the conjunctival flap covered 70% of the central and temporal cornea. A routine superficial lamellar keratectomy was performed to a minimum depth of 350 μm (see Video, Supplemental Digital Content, http://links.lww.com/ICO/A438). Briefly, a 350-μm restricted depth knife (BD Beaver Accurate Depth Knives; Beaver-Visitec International, Waltham, MA) was used to create the outlining incision; either a Martinez corneal dissector (Storz, St Louis, MO) or universal corneal scissors (Rumex International Co, Clearwater, FL)[25] was used for lamellar dissection, and universal corneal scissors was used to excise the corneal flap from the limbus.

A supplementary video of SKCAHF being performed in the right eye of an 8-year-old spayed female Boston Terrier (case not included in the clinical trial; see Video, Supplemental Digital Content, http://links.lww.com/ICO/A438).

Adjacent to the keratectomy site, 1 to 2 mL of balanced salt solution (BSS) was injected subconjunctivally to separate a very thin layer of conjunctival epithelium from the underlying substantia propria and Tenon capsule.[26] The conjunctiva over the bleb was dissected free from the underlying tissue, and meticulous dissection was performed to avoid perforating or placing excessive tension on the conjunctival flap. The conjunctival flap was advanced to completely cover the keratectomy site(s) and secured to the incision margin with cardinal sutures and simple continuous pattern using 8-0 or 9-0 polyglactin 910 (Ethicon, Somerville, NJ). A drop of topical ofloxacin, proparacaine, and atropine ophthalmic solutions was applied postoperatively. Patients were discharged with an Elizabethan collar to be worn for 2 to 3 weeks to prevent self-trauma; operated eye(s) were treated with topical ofloxacin ophthalmic solution q 6 to 8 hours, topical 5% NaCl ophthalmic ointment q 6 to 8 hours, and carprofen 2 mg/kg per os q 12 hours for 7 days. Patients were examined at 3 to 4 days and 2 weeks postoperatively. At the 2-week recheck, topical ofloxacin was discontinued, and topical neomycin–polymyxin–dexamethasone ophthalmic ointment q 8 to 12 hours was initiated and continued for the study duration [median (range) 12.3 (11.7–13.9) mo] at q 12 to 48 hours. The frequency of NaCl ophthalmic ointment was decreased to q 8 to 24 hours at 4 to 5 weeks postoperatively.

Owner Survey

Owner surveys were conducted at median 6.8 and 12.3 months postoperatively (see Appendix, Supplemental Digital Content, http://links.lww.com/ICO/A437). In the owner survey, owners were asked to recall the duration of corneal cloudiness before presentation, number of corneal ulcers, number of topical medications, and tolerability to use of topical 5% NaCl ointment before SKCAHF; semiquantitative scales were provided for the owner to estimate the quality of their dog's vision [1 (poor) through 10 (excellent)] and severity of corneal cloudiness [1 (mild) through 10 (severe)] before any treatment, with topical 5% NaCl treatment, and after SKCAHF. Owners were asked to categorize their dog's improvement in vision and corneal cloudiness as none, temporary, or permanent, and if temporary, to estimate how long the improvement lasted for. Owners then were asked to select from “yes” or “no” the answer that best described whether, in retrospect, all follow-up visits and SKCAHF were cost effective and whether they would recommend SKCAHF to owners of other dogs similarly affected.

Data Analysis

Percentage of cornea covered by conjunctival flaps was estimated using image analysis software (ImageJ, http://www.rsbweb.nih.gov/ij/). One-way analysis of variance (ANOVA) with a Student–Newman–Keuls post hoc test was used to evaluate the changes of corneal thickness over time. When data were not normally distributed, ANOVA on ranks or Kruskal–Wallis test were used. ANOVA on ranks was used for owner survey results. Data are presented as mean ± SD, with the exception of ordinal data from the owner surveys, which are summarized as median (range). Least squares linear regression was used to assess the relationship between the percentage of cornea covered by conjunctival flaps and the change in corneal thickness at 12.3 months postoperatively. A value of $P < 0.05$ was used to indicate significance for all analyses. In the following text, eyes that received SKCAHF are referred to as operated eyes, and eyes clinically unaffected with corneal edema that did not receive SKCAHF are referred to as nonoperated eyes.

Results

Nine dogs were included with a mean ± SD age and weight of 9.9 ± 1.3 years and 13.3 ± 9.6 kg, respectively (Table 1). Operated and nonoperated eyes had normal STT-1 and IOP of 21.0 ± 4.3 mm/min and 9.8 ± 4.4 mm Hg, respectively. One dog (case 9) had bilateral immune-mediated keratoconjunctivitis sicca, which was medically well controlled with tacrolimus 0.02% ophthalmic solution OU q 12 hours at study inclusion.

Median (range) duration of corneal edema before SKCAHF based on owner assessment and diagnosis by a veterinary ophthalmologist were 12.5 (5.5–36.5) and 3.5 (2–36) months, respectively. All dogs were comfortable preoperatively. Five dogs had one episode of corneal ulceration in the year preceding surgery, but no patients were ulcerated at study inclusion. Underlying causes of corneal edema were CED in 7 dogs and corneal endothelial degeneration in 2 dogs (Table 1).

The axial cornea was spared in all but one patient (case 1; 70% total corneal coverage); mean percentage of cornea covered by conjunctival flaps was 38.2% ± 10.8% (Fig. 1). Median (range) times of postoperative examinations were 2.2 (1.7–3.2), 6.8 (5.5–7.7), and 12.3 (11.7–13.9) months.

In Vivo Confocal Microscopy

Preoperative corneal edema precluded visualization of keratocytes and endothelium in some cases. Endothelial, anterior stromal keratocyte, and posterior stromal keratocyte densities of operated and nonoperated eyes were 1075 ± 226 (4 eyes), 1658 ± 490, 459 ± 93 (10 eyes), 522 ± 44 (6 eyes), 493 ± 16 (3 eyes), and 520 ± 75 (6 eyes) cells/mm^2, respectively, and were all below previously reported normal values for dogs for endothelial cells.[27,28] All CED cases demonstrated moderate to marked endothelial cell polymegathism and pleomorphism (Fig. 2). Keratocyte and endothelial cell densities in operated or nonoperated eyes did not significantly change over time (data not shown).

Two dogs (cases 2 and 9) were diagnosed with unilateral endothelial degeneration based on a normal endothelial density, endothelial cell morphology, and corneal thickness in the nonoperated eyes preoperatively and throughout the study period (Table 1). Both cases lacked evidence of intraocular disease or history of ophthalmic surgery; thus, the cause of the unilateral corneal endothelial degeneration was unknown.

Ultrasonic Pachymetry

Compared with preoperative values, central, superior, and temporal corneal thickness significantly decreased at 2.2, 6.8, and 12.3 months after surgery ($P < 0.05$); no significant differences were found between postoperative periods ($P > 0.05$; Fig. 3). Nasal corneal thickness did not significantly differ after surgery ($P = 0.265$). Inferior corneal thickness significantly decreased at 2.2 months ($P = 0.026$) after surgery; no significant difference was found at 6.8 ($P = 0.129$) and 12.3 months ($P = 0.289$) postoperatively or between postoperative periods ($P > 0.05$). Corneal thickness did not significantly differ in the nonoperated eyes over time in any location (data not shown). At 12.3 months post-operatively, there was a significant relationship ($P = 0.0159$) between the percentage of cornea covered by conjunctival flaps and decrease in central corneal thickness (CCT) as measured by USP (Fig. 4).

Fourier-Domain Optical Coherence Tomography

Full CCT was significantly decreased at 2.2 ($P = 0.001$), 6.8 ($P = 0.005$), and 12.3 months ($P = 0.033$) postoperatively when compared with before surgery; no significant difference was found between postoperative periods ($P > 0.05$; Fig. 5). Central stromal thickness was significantly less at all time points ($P \leq 0.045$) in comparison with before surgery. No significant difference was found for central epithelial thickness ($P = 0.263$) or central Descemet membrane (DM)–endothelial complex thickness over time ($P = 0.611$). In nonoperated eyes, full corneal, stromal, epithelial, and DM–endothelial complex thickness by FD-OCT did not significantly differ over time (data not shown).

Preoperatively, corneal cross-sectional images demonstrated moderate to marked increase in thickness because of edema and loss of orderly arrangement of the collagen fibrils, most notably in the anterior stroma (Fig. 6). In patients with severe edema (8 eyes of 5 dogs), anterior stromal bullae were observed. Postoperatively, corneal thickness decreased and the collagen fibrils appeared more orderly in 10 eyes (7 dogs). All anterior stromal bullae resolved postoperatively and did not recur during the study period. These changes were observed in central corneas, where neither keratectomy nor conjunctival flap was performed with the exception of case 1. Stromal fibrosis, identified as a homogeneous hyperreflective layer usually in the anterior stroma, became evident postoperatively in 11 eyes (8 dogs); this was most notable in those with diffuse involvement (>80% cornea affected), a CCT of 1000 mm or more, or chronic (>12 mo) corneal edema and remained unchanged over time. In 6 eyes with corneal melanosis, the extent and density of melanin were unchanged after surgery.

Topical Medications

Frequency of topical 5% NaCl administration significantly decreased ($P < 0.05$) from 4.6 ± 1.0 times daily preoperatively to 2.7 ± 1.4 and 3.0 ± 1.0 times daily at 6.8 and 12.3 months postoperatively, respectively. Topical steroid administration significantly increased ($P < 0.05$) from 0.3 ± 0.4 times daily preoperatively to 1.6 ± 0.6 and 1.6 ± 0.6 times daily at 6.8 and 12.3 months postoperatively, respectively. Three patients (cases 4, 5, and 7) had both topical ophthalmic medications discontinued 1 to 2 weeks before the 6.8-month examination and experienced worsening of corneal edema. Thus, all patients were maintained on topical NaCl and steroid ointments postsurgery, though the frequency of topical NaCl was decreased.

Postoperative Examination Findings and Complications

Increase in corneal clarity and visualization of the iris were notable in 5 eyes (4 dogs) (Fig. 7). In these 5 eyes, the extent of the corneal edema ranged from focal (case 3), extensive (case 7), to diffuse (case 6 OU, case 4 OD) preoperatively, and decrease in CCT as measured by FD-OCT ranged from 9% to 41% at 12.3 months postoperatively. Conjunctival flap pigmentation was noted in 6 eyes (5 dogs) at 12.3 months postoperatively; pigmentation was mild (<25%) in 2 eyes, moderate (25%–50%) in 2 eyes, and profound (>50%) in 2 eyes. All eyes were assessed as comfortable postoperatively; no complications including corneal ulceration were observed during the study period.

Owner Survey

All (9/9) owners responded to the survey at 6.8 months, and 8/9 owners responded at 12.3 months. A significant improvement was observed in overall vision and corneal cloudiness at 6.8 and 12.3 months after SKCAHF ($P < 0.05$, Table 2). Owners of case 6 reported mild decline in vision at 12.3 months postoperatively. On examination, corneal thicknesses were relatively unchanged in both eyes from 6 months previously, but bilateral cataract progression was identified. At 6.8 and 12.3 months postoperatively, 100% of the owners (9/9 and 8/8, respectively) stated that the surgery was cost effective, they were satisfied with the surgery, and they would recommend this surgery to owners of other dogs similarly affected.

Discussion

Our results demonstrate that SKCAHF is a viable surgical alternative for treatment of canine progressive corneal edema. The use of autologous conjunctiva eliminates the need for donor tissues. SKCAHF can easily be performed by ophthalmologists with basic microsurgical skills without the need for specialized donor-harvesting instruments.[23,24] In this case series, the improvement in corneal edema lasted for at least 1 year with resolution of corneal bullae and reduction in the frequency of topical NaCl. Mean number of corneal ulceration episodes decreased after SKCAHF when compared with before surgery, and this decrease approached statistical significance. No complications were noted in any patients. Lastly, owners reported improvement in vision and corneal clarity and felt that the surgery was worthwhile and cost effective.

Gundersen described partial and complete conjunctival flaps to treat focal edema with successful vision preservation in the remaining cornea and to increase comfort without vision restoration, respectively.[10,11] Partial conjunctival flaps have been used by both physician and veterinary ophthalmologists since its first description; however, previous studies have only observed and did not quantify improvement in corneal edema.[10,11,13,23,24,29,30] This study demonstrates that SKCAHF results in significant thinning of the cornea for up to 12.3 months postoperatively by reducing corneal edema in dogs with corneal endothelial dysfunction. We also demonstrated that the percentage of conjunctival flap coverage is directly correlated with the degree of corneal thinning achieved postoperatively at 12.3 months. Larger flaps covering a greater percentage of the peripheral cornea may have resulted in stabilization of corneal thickness for a longer period in some patients. Thus, increasing the depth and total area of corneal stroma removed and increasing conjunctival flap coverage may result in further improvement in outcome, and future study is warranted.

The precise mechanism(s) by which corneal edema is improved with SKCAHF is unknown. Gundersen had theorized that the stromal edema takes the path of least resistance through the keratectomized area.[10,11] In support of this theory, we have observed an improvement in corneal clarity of adjacent nonkeratectomized cornea immediately after the superficial keratectomy was completed and before the conjunctival flap was placed. Thus, it is likely that the conjunctival flap is essential in maintaining corneal deturgescence by providing an alternate route for fluid drainage via conjunctival vessels. Furthermore, it is possible that removal of stroma may not be required, and epithelial removal followed by conjunctival flap may also achieve similar results to our study. We were unable to test these theories, and future studies comparing superficial keratectomy without conjunctival flap, epithelial removal with conjunctival flap, and SKCAHF are required. Recent variations of the Gundersen flap in human patients, in which only epithelial removal was performed before the conjunctival flap[30] or conjunctival flap and amniotic membrane placement,[13] achieved surgical success in all cases in terms of promoting a stable ocular surface with resolution of ocular discomfort; however, corneal thicknesses were not compared pre- and postoperatively.

In this study, discontinuation of topical steroids resulted in worsening of corneal edema in 3 patients, which resolved once topical steroids were reinstituted. Canine eyes have a more robust inflammatory response versus humans after surgical intervention[31]; thus, all patients were continued on topical steroid ophthalmic ointment for at least a year postoperatively. Previous reports of Gundersen flaps in humans achieved surgical success, defined as resolution of ocular discomfort, without long-term topical steroid use.[11,20,30] Therefore, long-term steroid use may be unnecessary in humans and likely contraindicated because of the risks of chronic steroid use including cataracts and ocular hypertension.[32]

Canine CED is an excellent spontaneous large animal model for human FECD given the striking similarities in clinical features including older age of onset,[17,19] female predisposition,[17,19] bilateral involvement,[17–19] decreased endothelial cell density,[19,33] and endothelial polymegathism, and pleomorphism.[19,33] Similarities between canine CED and FECD also extend to changes seen in the stroma. A study using IVCM showed posterior keratocyte density to be higher in FECD patients compared with controls.[34] In addition, Hecker et al[35] found that keratocyte density in the entire cornea was significantly less in FECD versus control patients. Similarly, in our study of canine CED, the densities of anterior keratocytes and posterior keratocytes of study and nonoperated eyes, respectively, were lower compared with the cell densities reported in normal dogs.[27] Furthermore, anterior and posterior keratocyte densities in our study did not significantly change over time despite the improvement in corneal thickness, which suggest a permanent loss in keratocyte density. The mechanism by which keratocytes are lost in canine CED and FECD are unknown but may be secondary to endothelial dysfunction and apoptosis triggered by cytokine release from epithelial cells.[35] The latter mechanism is another reason to investigate the effects of epithelial removal with or without conjunctival flap on corneal edema.

In summary, SKCAHF results in significant improvement of corneal thickness by reducing corneal edema and is a viable surgical treatment option for corneal edema associated with corneal endothelial decompensation in dogs. This technique may represent a viable option in humans affected with bullous keratopathy where visual potential or access to corneal transplantation is limited.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

External photographs of SKCAHF showing different locations and percentage of coverage by conjunctival flaps. The left (A) and right (B) eyes of a 10.8-year-old spayed female Shih Tzu (case 6) 3 days after SKCAHF with the conjunctival flaps covering 36% of cornea in each eye. The right eye (C) of a 10.5-year-old neutered male Cocker Spaniel (case 9) 13 days after SKCAHF with the conjunctival flap covering 36% of the cornea. The right eye (D) of a 8.1-year-old spayed female Boston Terrier (case 7) 9 days after SKCAHF with the conjunctival flap covering 46% of the cornea.

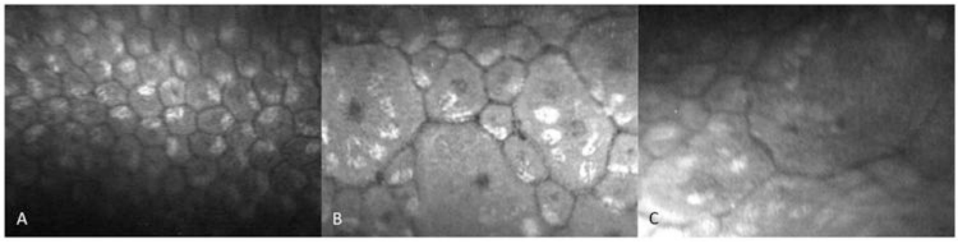

Figure 2.
Representative IVCM images of corneal endothelium from a normal canine eye (A) and eyes affected with canine CED (B, C). A, The right (nonoperated) eye of an 11.7-year-old spayed female Dalmatian (case 2) with normal endothelial density of 2474.2 cells/mm^2. B, The left and (C) right eyes of an 8-year-old spayed female Boston Terrier (case 7) showing marked polymegathism and pleomorphism and decreased cell densities (left 1576.3 cells/mm^2; right 1099.6 cells/mm^2). Only the right eye (C) of this patient was clinically affected with corneal edema and received SKCAHF.

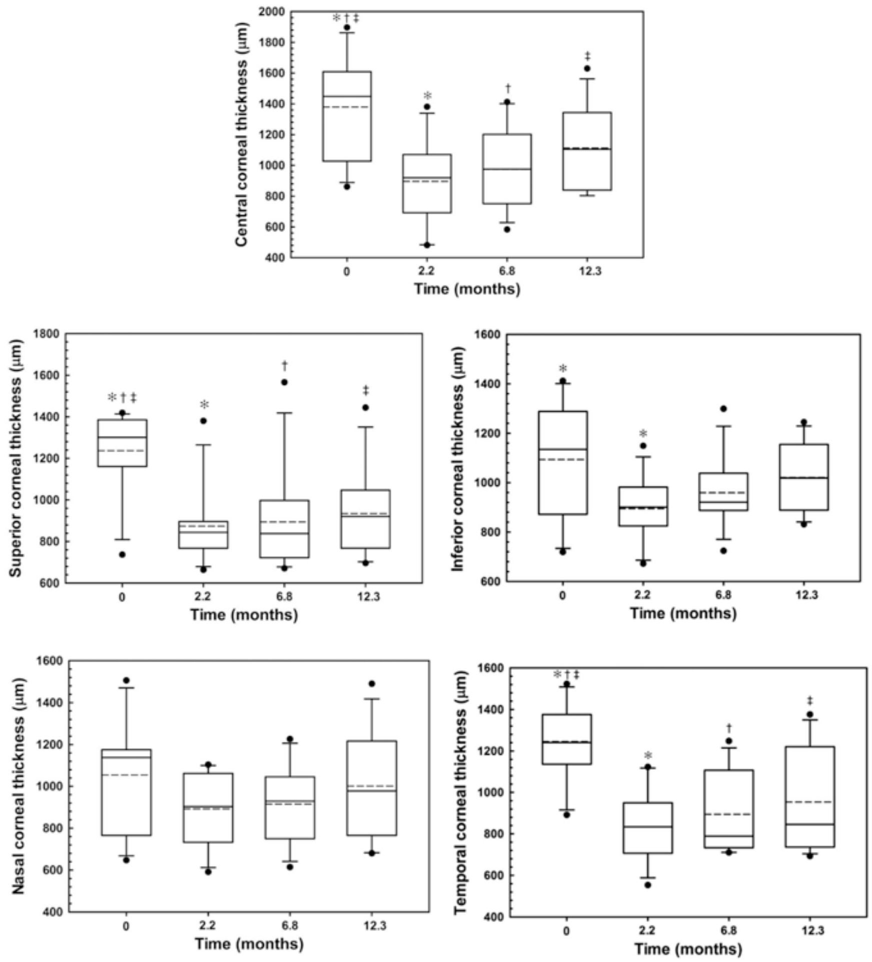

Figure 3.

Corneal thickness measurements by USP (Pachette 3) showed significant decrease in central, superior, and temporal regions throughout the postoperative period. Inferior corneal thickness decreased at 2.2 months, but no significant decrease was found at 6.8 and 12.3 months compared with preoperative thickness. Nasal corneal thickness did not significantly change after surgery. Box plots depict median (solid line), mean (dashed line), and 25th and 75th percentiles, and whisker plots show 10th and 90th percentiles; black circles indicate outliers. The *P* values were determined by a Student–Newman–Keuls post hoc test (central, inferior, temporal, and nasal) or Kruskal–Wallis test (superior). $^{*}P < 0.05$; $^{\dagger}P < 0.05$; and $^{\ddagger}P < 0.05$.

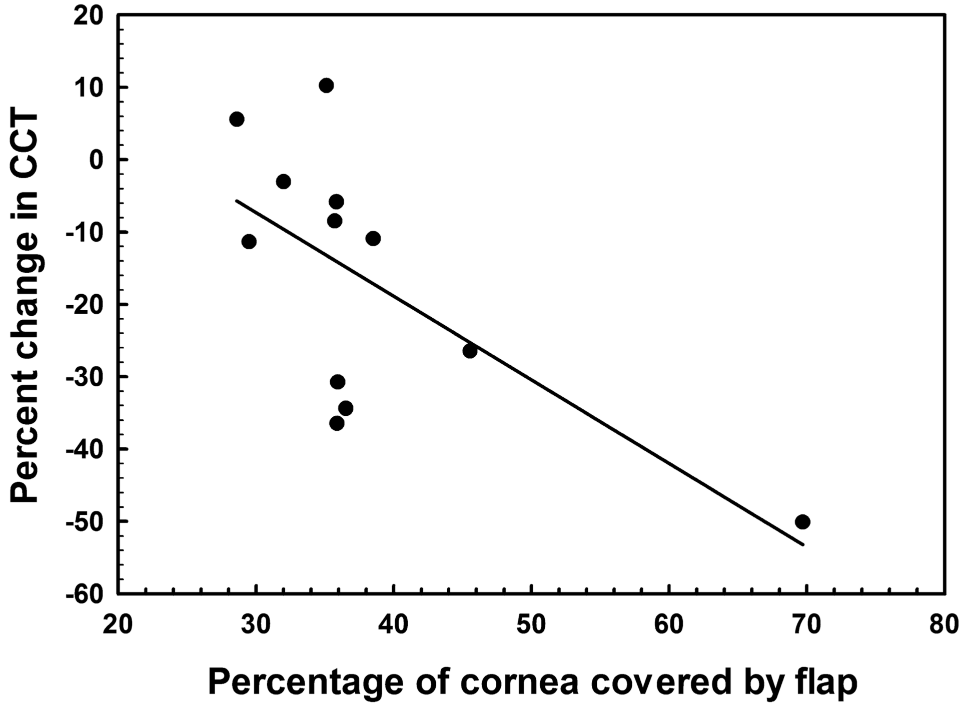

Figure 4.

The area of conjunctival flap coverage and change in CCT by USP at 12.3 months showed a significant direct linear relationship ($P = 0.0159$) between area covered by the flap and subsequent corneal thinning in 12 eyes of 9 patients receiving a SKCAHF surgery.

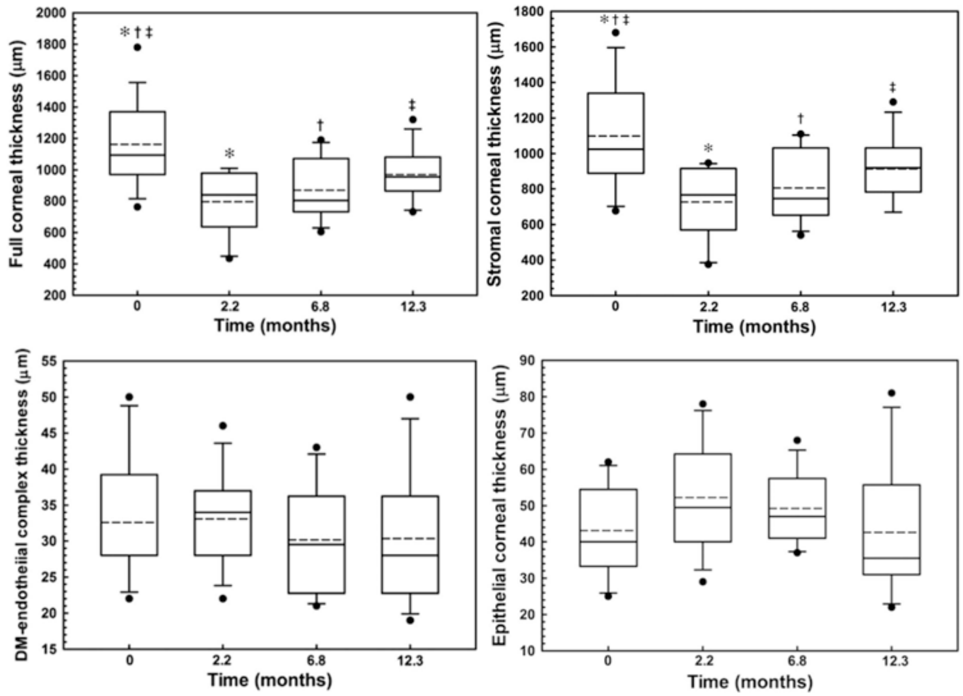

Figure 5.

Central corneal full and stromal thickness significantly decreased throughout the postoperative period after SKCAHF as measured by FD-OCT. Although corneas thinned significantly postoperatively, no significant additional changes were found with increasing time from surgery. The change in corneal thickness was attributable to changes in the stroma. Epithelial and DM–endothelial complex thickness did not significantly change at any time point. Box plots depict median (solid line), mean (dashed line), and 25th and 75th percentiles, and whisker plots show 10th and 90th percentiles; black circles indicate outliers. The P values were determined by a Student–Newman–Keuls post hoc test (full, stromal, and epithelial) or Kruskal–Wallis test (DM–endothelial complex). *$P \leq 0.001$; †$P < 0.01$; and ‡$P < 0.05$.

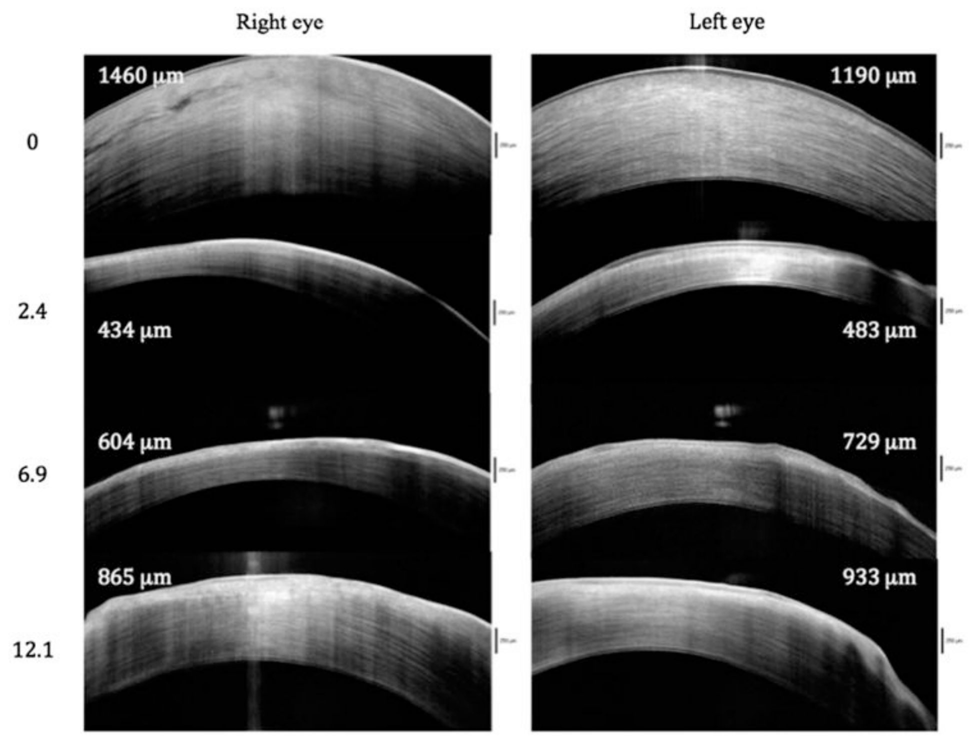

Figure 6.

FD-OCT images of central cornea of both eyes from a 10.8-year-old spayed female Shih Tzu (case 6) before and after SKCAHF at 2.4, 6.9, and 12.1 months. CCT measurements are indicated on each image. Preoperatively, the stroma was markedly thickened, with stromal edema, and loss of the orderly arrangement of the collagen fibrils was noted. Corneal thickness and stromal edema continued to decrease up to 6.9 months. Collagen fibrils seemed more orderly at 6.9 months. At 12.1 months, the corneal thickness had increased but remained less than the preoperative value. Undulated anterior surface in the images from the left eye represent the conjunctival flaps. Stromal fibrosis, which seems as homogenous hyperreflective layer in the anterior stroma, was more evident postoperatively.

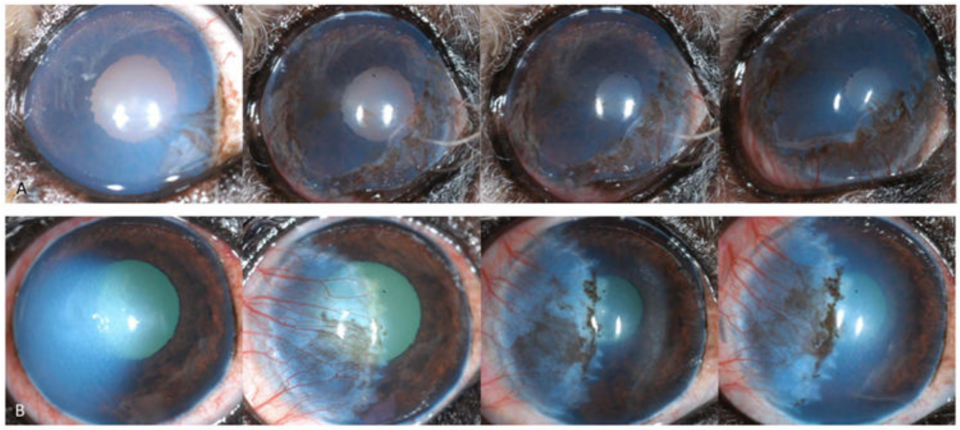

Figure 7.

External photographs before and at approximately 2, 6, and 12 months after SKCAHF. A, The right eye of an 11.7-year-old neutered male Cocker Spaniel and Poodle mix (case 4). CCT measurements by USP were 952, 683, 751, and 923 μm before and at 2.2, 5.5, and 12.1 months, respectively. The conjunctival flaps are located temporally and inferionasally and became partially pigmented. Percentage of cornea covered with conjunctival flap was 32%. B, The right eye of an 8-year-old spayed female Boston Terrier (case 7). CCT measurements by USP were 1897, 719, 1000, and 1395 mm before and at 2.6, 6.9, and 13.0 months, respectively. The conjunctival flap was located temporally and became partially pigmented. Percentage of cornea covered by conjunctival flap was 46%. She also developed an arc-shaped subepithelial mineral deposit in the nasal paraxial cornea, presumably secondary to chronic topical ophthalmic steroid administration. These deposits were most notable at the 6.9-month recheck and became less obvious at the 13month recheck.

Table 1

Signalment, Operated Eye(s), Preoperative Endothelial Density, and CCT by FD-OCT for 12 Eyes From 9 Dogs That Were Included in the Study*

Patient	Age, yr	Sex	Breed	Eye	ED, Cells/mm^2	CCT, μm	Extent	Diagnosis
Case 1	9.8	FS	Dachshund	OD*	NA	1340	Diffuse	CED
				OS	1065.0	425	None	
Case 2	11.7	FS	Dalmatian	OD	2474.2	747	None	Endothelial degeneration
				OS*	819.8	1100	Diffuse	
Case 3	9.4	FS	Pug/chihuahua mix	OD*	1364.9	1090	Focal	CED
				OS	1430.0	617	None	
Case 4	11.7	MN	Cocker spaniel/poodle mix	OD*	NA	837	Diffuse	CED
				OS*	NA	762	Diffuse	
Case 5	9.1	FS	German shorthair pointer	OD*	NA	1030	Diffuse	CED
				OS*	NA	1050	Diffuse	
Case 6	10.8	FS	Shih Tzu	OD*	NA	1460	Diffuse	CED
				OS*	NA	1190	Diffuse	
Case 7	8.1	FS	Boston terrier	OD*	1099.6	1400	Extensive	CED
				OS	1576.3	505	None	
Case 8	8.2	FS	Japanese chin	OD*	1016.5	1780	Extensive	CED
				OS	1453.5	638	None	
Case 9	10.5	MN	Cocker spaniel	OD*	NA	911	Extensive	Endothelial degeneration
				OS	1946.8	641	None	

The extent of the corneal edema was described based on the percentage of cornea affected: focal (<40% affected), extensive (40%–80% affected), and diffuse (>80% affected).

*Study eyes that were clinically affected with corneal edema and underwent SKCAHF.

ED, endothelial density; FS, spayed female; MN, neutered male; NA (not applicable), unable to visualize endothelium because of severe corneal edema and/or fibrosis; OD, right eye; OS, left eye.

Table 2

Summary of Owner Survey Results With Scoring on Vision (1 = Poor, 10 = Excellent) and Corneal Cloudiness (1 = Mild, 10 = Severe)*

	No Treatment	Sodium Chloride	6.8, months	12.3, months
Overall vision	5 (1–9) *	5 (3–9)	8 (5–10) *	8 (5–9)
Corneal cloudiness	9 (5–10) *	7 (1–9)	4 (3–8) *	5.5 (3–7) *

Data are shown as median (range).

*Statistically significant at $P < 0.05$.