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Optical Coherence Tomography Imaging of the Palisades of Vogt to Assist Clinical Evaluation and Surgical Planning in a Case of Limbal Stem Cell Deficiency

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Abstract

Purpose—To describe the use of volumetric optical coherence tomography (OCT) imaging to assist evaluation of a patient referred for autologous limbal stem cell transplant.

Methods—This is a case report of a fifty year-old patient presenting with unilateral limbal stem cell deficiency who was referred for autologous limbal stem cell transplant. The presence of Salzmann's nodules in the donor eye raised questions about the efficacy of transplantation, prompting examination of both eyes using volumetric OCT imaging to determine whether there were palisades of Vogt (POV) present. Image volumes were acquired in all clock hours and were compared against those of an age-matched normal subject.

Results—Palisades were found in both eyes, although in both eyes there were fewer palisade ridges, and those that were present were not as distinct as those of the normal subject. The OCT volumes also showed that stromal scarring was present only in the anterior stroma of the intended transplant eye. These findings suggested that the patient may be able to sustain a deep anterior lamellar keratoplasty (DALK) without an autologous transplant, which would spare any insult to the opposing eye and require less surgery to restore vision in the affected eye. Nine months post-surgical follow up revealed significant improvement in visual acuity and no scar tissue development.

Conclusion—OCT evaluation of the POV provides detailed information to the clinician that may assist in diagnosis and evaluation of patients prior to transplantation. Further development of this technique is necessary to make it clinically available.

Keywords

Palisades of Vogt; Limbal stem cell deficiency; Corneal transplant

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Introduction

Replenishment of healthy corneal epithelium relies on proper functioning of limbal epithelial stem cells (LESCs)[1] located in the palisades of Vogt (POV), a series of fibrovascular ridges located primarily in the superior and inferior corneal limbus. This region has a unique configuration in each person, remodels over time, and contains stem cells that divide and migrate into the cornea in a centripetal pattern to restore the corneal epithelium[2–4]. Loss of the POV and the resident LESCs produces limbal stem cell deficiency (LSCD)[5], which is a clinically important cause of corneal blindness that remains a difficult and challenging condition for clinicians to manage[6]. Evaluation of LSCD patients is currently conducted with slit lamp and with confocal microscopy. However, the restricted field of view in slit lamp and the direct contact required for confocal microscopy are disadvantages when evaluating patients for possible transplant. Recently, OCT was described as an imaging method that can be used to visualize the POV[7], which raises the possibility of using this rapid, non-contact imaging technique to acquire more detailed information about the status of the palisades prior to surgery.

Treatment of unilateral LSCD patients may include autologous limbal stem cell transplant, followed by either a DALK or penetrating keratoplasty (PK) to restore visual acuity. During autologous limbal stem cell transplant, several clock hours of the limbal region of the healthy eye are transplanted into the injured eye. Risk factors for autologous limbal stem cell transplant include epithelial metaplasia, failure of the stem cells to replicate in the host eye and decrease in the amount of stem cells in the donor eye, which risks destabilizing the ocular surface of the healthy eye[6,8]. Here we report a case of a patient presenting with unilateral LSCD and a possible complication in the donor eye, which prompted examination of the eye by volumetric OCT imaging to assist in assessing the viability of autologous limbal stem cell transplant. Image processing methods were employed to register and resegment the image volumes to visualize the limbus and the POV. The results of this imaging assisted in determining course of management.

Case Report

A fifty year old female with unilateral LSCD, secondary to long-standing contact lens wear (Figure A) was referred for autologous limbal stem cell transplant. She had previously undergone keratectomy with amniotic membrane graft on that eye. Her best-corrected visual acuity was hand motion (HM) at presentation. The prospective donor eye had several Salzmann's nodules indicating a non-inflammatory, progressive degenerative corneal condition (Figure B). The nodules were located in at the corneal limbal margin, which raised questions about the possible impact on the POV, and about whether harvesting tissue from that eye might have significant impact on the future health of the eye. Additional information about the status of the limbus and palisades was desired prior to recommending transplant. The patient was consented into an IRB approved study and image volumes (4×4 mm region of tissue at 300×300×1024 voxels) were acquired around the circumference of the corneal limbus with a Bioptigen SD-OCT system (Bioptigen Inc., Durham, NC and SuperLum Ltd., Ireland) to determine the presence and general location of the POV. Image processing was done in FIJI[9] to register each volume to correct for motion artifact prior to

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smoothing and straightening each volume manually along the basement membrane of the limbus. The Volume Viewer plugin was used to segment the volumes in axial, sagittal and coronal views to confirm location of the palisade images in the epithelium of the limbus (Figure E). Coronal views of the limbus were compared to those of an age-matched normal subject (Figure F - K).

In normal subjects, palisades are found primarily in the inferior and superior limbus[10], which was also observed in the patient. The normal subject had a clear, regular palisade ridge with many palisades present (Figure H & K). In contrast, the patient had a less distinct palisade ridge with fewer palisades in diseased eye (Figure F & I) as well as donor eye (Figure G & J), and this was consistent in all volumes. The presence of palisades in both eyes of the patient was determined to be approximately the same, which suggested that transplant would not be beneficial in this case. Further examination of the OCT volumes revealed that the stromal scarring present the diseased eye was located in the anterior stroma, and that the posterior stroma appeared to be unaffected. The equal presence of palisades in both eyes suggested that it might be possible for this patient to sustain a transplant without undergoing autologous limbal stem cell transplant, and the pattern of scarring suggested a DALK rather than a PK as the treatment of choice.

Findings from the imaging and possible courses of treatment were discussed with the patient and subsequently DALK with amniotic membrane graft was conducted. Nine months post-surgical follow up demonstrated improved best-corrected visual acuity 20/50 and no scar tissue development. The patient was very happy with visual and aesthetic outcome (Figure C).

Discussion

The POV were first documented in the late 18th century, but have only been ascribed a function in the last 35 years. Non-contact, in-vivo imaging of the POV is still an experimental technique, but this imaging offers the opportunity to explore the relationship between the morphological presentation of palisades and different ocular conditions, which may facilitate diagnosis, treatment planning and follow-up of conditions that threaten the cornea. In this case, the patient had one eye that was sustaining a clear cornea even with the presence of Salzmann's nodules, so we could compare the palisades in her clear cornea to those found in diseased eye, as well as comparing her palisades to those of an age matched normal. The similarity of the palisades in both of her eyes suggested that she might have the necessary stem cells in both eyes to sustain a transplant without a prior allograft, despite the fact that her palisades patterns did not match those of the normal. This conclusion was borne out by the successful outcome of the surgery and the success of this transplant also suggests that OCT imaging might offer finer levels of discrimination when diagnosing LSCD.

Palisade imaging may be helpful for refining diagnosis in addition to assessing the potential for successful autologous limbal stem cell transplant in patients that present with presumptive LSCD. OCT evaluation of the limbus prior to autologous limbal stem cell transplant may allow more targeted harvesting of palisade regions, or may contraindicate performing autologous limbal stem cell transplant. Further investigation into the

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characteristics and presentation of palisades in-vivo is necessary to define the morphology of palisades in different conditions and to determine whether changes in palisades can be used to track or diagnose corneal conditions. The single case discussed here is not sufficient to conclusively demonstrate that this technique is universally applicable in the clinic. Similarly, the processing used to segment the volumes in this case included a manual component that would need to be refined before becoming clinically useful. However, this case does demonstrate that high-resolution image volumes acquired with OCT provide detailed information that was heretofore unavailable, and that this information may assist in accurate clinical evaluation of complicated corneal cases.

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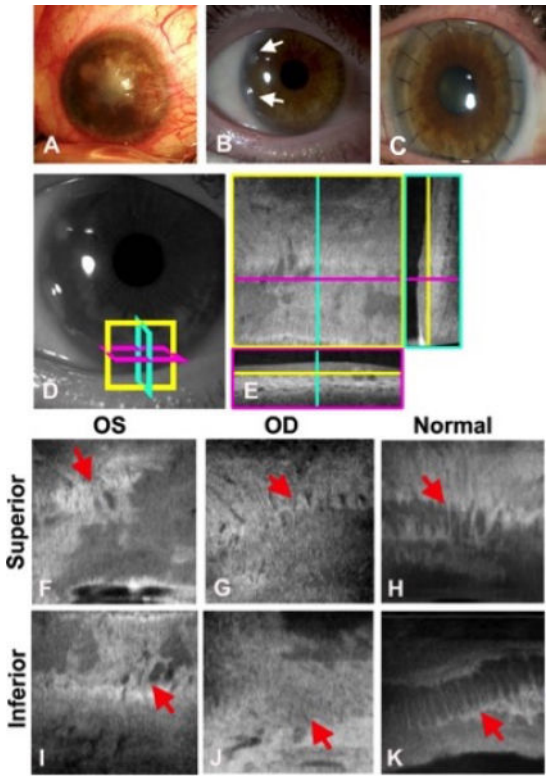

Figure.

A: Preoperative image of diseased eye shows elevated scar tissue in the center with corneal neovascularization and pseudo pterygium nasally. B: Prospective donor eye with Salzmann's nodule nasally (white arrows). C: Diseased eye, 9 months after DALK and amniotic membrane graft. Visual acuity improved from HM to 20/50. D & E: While segmenting OCT volumes, coronal (yellow outline), axial (blue outline) and sagittal (magenta outline) views were used to make sure that the images displayed were acquired at the level of the basement membrane. F-K show OCT volumes segmented along the epithelial basement membrane reveal palisades (red arrows) in the left (F & I) and right (G & J) eye of the patient and (H & K) the age-matched normal subject. F - H show palisades from the superior limbus, I - K from the inferior limbus.