

# ULTRAHIGH RESOLUTION OPTICAL COHERENCE TOMOGRAPHY FOR DETECTING TISSUE ABNORMALITIES OF THE ORAL AND LARYNGEAL MUCOSA: A PRELIMINARY STUDY

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**Abstract:** Optical coherence tomography (OCT) is an imaging technology that provides cross-sectional images without biopsy of subsurface tissue structure at approximately 10 micrometer resolution to a depth of 1.5 mm using backscattered light from the tissue. OCT has shown promising in imaging normal upper airways and in various disorders. The use of OCT to image the upper airways during diagnosis and treatment of a vast array of disorders continues to develop along with innovative surgical techniques, of patients in anesthesia.

Monitoring the benign cellular and molecular events resulting in e.g. edema, in the clinic online is of great interest. There is a need to get information in the clinic about the normal histology of functioning mucosa compared with disorders causing edema especially at the inflammatory process level. The main interesting point is to find out whether it is related to infection, acid reflux, allergy or a fourth condition. Long-range OCT using Doppler OCT is providing useful clinical applications for diagnostic and therapeutic laryngeal procedures of the vocal folds (1). Till now a probe for oral examination of the mucosa with ultrahigh resolution OCT has been established.

**Keywords:** In vivo optical coherence tomography, upper airways, mucosa, OCT

## I. INTRODUCTION

Optical coherence tomography (OCT) is an imaging technology that provides cross-sectional images without biopsy of subsurface tissue structure at approximately 10 micrometer resolution to a depth of more than 1.5 mm using backscattered light from the tissue. OCT has shown promising in imaging normal upper airways and in various disorders. The use of OCT to image the upper airways during diagnosis and treatment of a vast array of disorders continues to develop [1], along with innovative surgical techniques, of patients in anesthesia, eventually combined with confocal endomicroscopy [2].

A first full field highspeed and long-range OCT in vivo of the vocal folds was made recently [3]. Cross sectional images during phonation have also been

made [4]. In 1997 the epithelium, lamina propria and submucosa in the larynx were described with OCT in the larynx [5], and comparison of OCT pictures verified with histology based on biopsies have been made. Endonasal approach has been made to the larynx as well as automatic working adjustments to the working area [6].

Monitoring the benign cellular and molecular events resulting in e.g. edema, in the clinic online is of great interest. There is a need to get information in the clinic about the normal histology of functioning mucosa compared with disorders causing edema especially at the inflammatory process level. The main interesting thing is to find out whether it is related to infection, acid reflux, allergy etc.

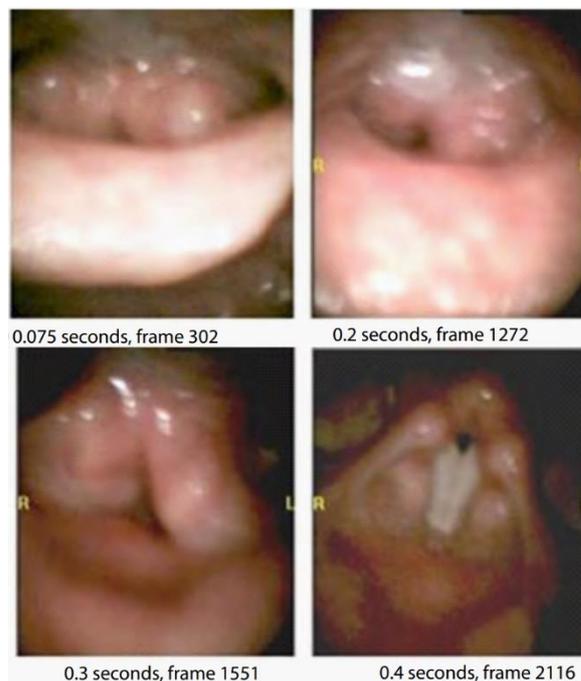


Fig 1. Frames taken from high-speed video set on recording 4000 pictures per second. The picture, at frame 1272 shows the appearance of mucus in the larynx, and shortly after (frame 1551) it is reduced. On frame 2116, the mucus has disappeared. The process took a total of 0.2 seconds [14].

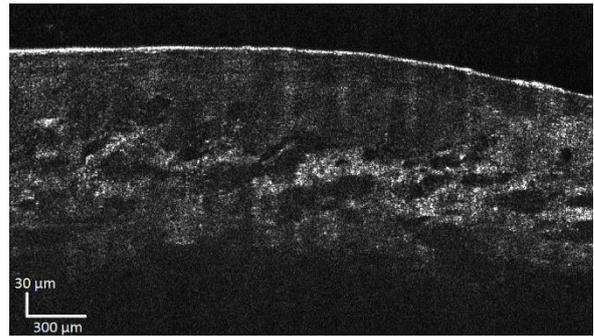
Long-range OCT using Doppler OCT is providing useful clinical applications for diagnostic and therapeutic laryngeal procedures of the vocal folds. Till now a probe capable of oral examination of the mucosa with the ultrahigh resolution (UHR) OCT has been established in our laboratory to be combined with highspeed films of the upper airways. And we can show some preliminary pictures of the oral mucosa.

## II. METHODS and III. RESULTS

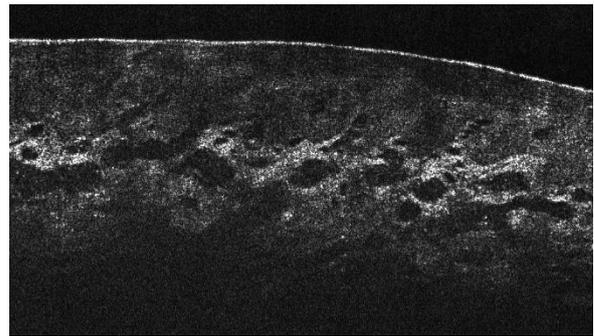
The OCT system applied in this study is an ultrahigh resolutions system constructed in-house. The setup is based on a supercontinuum source from NKT Photonics providing a large near-infrared band centered at approximately 1.3 micrometers. The light is forwarded to a beam splitter after which a sample and a reference mirror are exposed. The returning combined light signal is relayed to a spectrometer (Wasatch Photonics) detecting interferometric signals in a wavelength range of 1.074-1478 micrometer. The spectra detected are resampled, dispersion compensated, and attenuation corrected. The system demonstrates an axial (depth) resolution below 3 micrometers, a lateral resolution of 6 micrometer, a sensitivity of 90 dB and a line rate of 76 kHz. The imaging depth and maximum field of view are 2 mm and 8 mm, respectively. In order to interface the lining oral mucosa, a handheld probe was a necessity. The in-house constructed probe is described in [7, 8]

For the larynx a probe has earlier been developed through the nose and orally also in laboratories for online use of OCT without ultrahigh resolution. The new aspect is a probe trans orally where ultrahigh resolution OCT can be combined with our highspeed films of 4000 pictures per second (Richard Wolf GmbH) which we have used clinically for nearly 10 years. The highspeed films are only showing the surface of the laryngeal structures, but in pathology a combination with ultrahigh resolution OCT will give more information about the mucosal function also in the larynx.

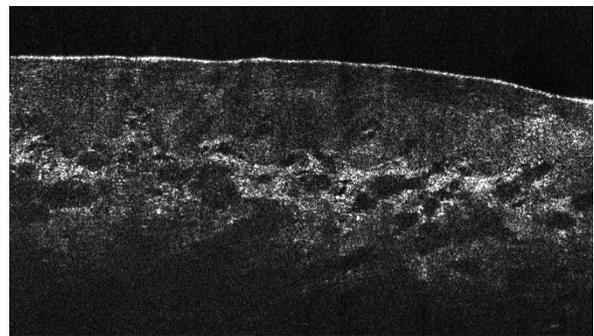
Ultrahigh resolution OCT images presented, show the oral lining mucosa in depth. B-scans show fine details of the transition from the epithelium to the lamina propria with information of blood vessel morphology. Three scans are presented to represent the information content provided by ultrahigh resolution OCT.



*Fig 2. In vivo optical coherence tomography of the oral mucosa of the inside of the lower lip. Scalebars for reference.*



*Fig 3. In vivo optical coherence tomography of the oral mucosa of the inside of the lower lip. This area is rich in blood vessels.*



*Fig 4. In vivo optical coherence tomography of the oral mucosa of the inside of the lower lip.*

## IV. DISCUSSION and V. CONCLUSION

It is possible to make quantitative assessment of the structure characteristics, e.g. fibrosis, atrophy, tissue inflammation, capillary loop density, vessel morphology as well as glands, and changes during treatment online with this setup. This means that the OCT method can document tissue changes with pharmacological and other medical interventions [9]. Another interesting aspect is development of the epithelium of the upper airways in childhood [10], especially of the vocal folds during puberty, where the hormonal cellular effect lacks understanding [11, 12, 13].

Documentation of pathology in benign disorders of the upper airway in the clinic is insufficient. There is a lack of differentiation possibilities for treatment documentation. The mucosa function is also of extreme interest to document pathology in singers [3,10]. Ultrahigh resolution OCT is a promising candidate for detecting tissue abnormalities of the upper airway mucosa in the clinic. Especially irregularities related to the junction between the epithelium and lamina propria and the thickness of epithelium is easily delineated by this significantly aid diagnosis also in other mucosal regions. Quantitative diagnoses are of interest with this ultrahigh resolution OCT setup in the arytenoid region behind the vocal fold for laryngopharyngeal reflux, and the vocal folds in cases where direct laryngoscopy is without indication. Evidential documentation is in demand in order to correlate online (often acute) laryngeal disabilities, with highspeed films [14]. Another interesting aspect is the development of mucosa especially on the vocal folds during puberty, an online approach with presentation of the throat mucosa will help us with diagnosis and treatment [15, 16].

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