Dental Calculus Image Based on Optical Coherence Tomography

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Abstract: *In this study, the dental calculus was characterized and imaged by means of swept-source optical coherence tomography (SSOCT). The refractive indices of enamel, dentin, cementum and calculus were measured as 1.625±0.024, 1.534±0.029, 1.570±0.021 and 1.896±0.085, respectively. The dental calculus lead strong scattering property and thus the region can be identified under enamel with SSOCT imaging. An extracted human tooth with calculus was covered by gingiva tissue as in vitro sample for SSOCT imaging.*

Key words: *Optical coherence tomography, periodontitis, subgingival calculus*

INTRODUCTION

Optical coherence tomography (OCT) has been widely used in many clinical applications, including gastroenterology [1], ophthalmology [2], dermatology [3] and dentistry [4]. In dental science, OCT can be of a good tool for assessing early caries [5], oral cancer [6] and periodontal diseases [7]. Periodontitis is one of the major chronic infectious diseases in the oral cavity and the prevalence of the periodontitis is more than 50% among the population [8]. Besides, recent studies indicated that there exist certain correlations between periodontitis and various systemic diseases [9]. The traditional diagnosis of subgingival calculus is based on clinical examination by periodontal probing and radiographs. The poor reliability and reproducibility of periodontal probing makes it difficult to monitor the progression of periodontal destruction and the effects of treatments [10]. The radiography can determine the level of bone-related destruction but only for subgingival calculus that located on the proximal surface of tooth. In addition, the radiation exposure is accompanied with radiography measurement. OCT may provide a good periodontat monitoring tool because it is a non-invasive, non-destructive, non-radiated and real-time monitoring method. In this study, we demonstrate a subgingival calculus detection method based on swept-source OCT (SSOCT). The refractive indice of enamel, dentin,

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cementum, and dental calculus were measured for dental tissue characterization. The results show a good feasibility of dental calculus diagnosis based on SSOCT.

RESULTS

1. SSOCT system

A SSOCT system was built with 1310 nm swept source laser s a broadband light source. The fiber-based Mach- Zehnder interferometer is adopted with two couplers, one is 99:1 and another is 50:50, and two optical circulators. The balance detector was utilized for interference detection and then the data acquisition card was used for PC-photodector interfacing.

2. Refractive indices measurement

The refractive index determines the optical property of material. In previous studies [11], the refractive index of a highly scattering sample can be estimated from OCT measurement (shown as Fig. 1). The lengths of upper part and lower part are defined as z and z' and the refractive index is:

$$\mathrm{n} = 1 + \frac{z'}{z}$$

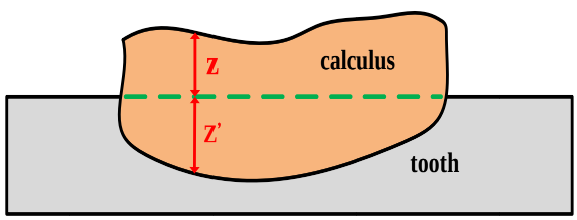
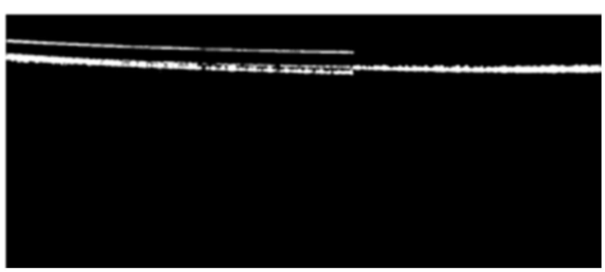


Figure 1 The SSOCT image of refractive index calculus scheme of dental calculus.

Figure 2 shows the OCT images of glass and enamel samples. Each sample was polished as a thin slice for SSOCT measurement. The refractive index of glass was measured for system calibration. The refractive index of glass is known as 1.503. Table 1 lists the refractive indices of enamel, dentin, cementum and calculus.



(a)

(b)

Fig. 2 SSOCT images of (a) glass, (b) enamel.

3. In-vitro dental calculus imaging

For feasibility study of subgingival calculus detection, a piece of porcine gingiva tissue with 0.3 mm thickness was used to cover on the tooth sample. Figure 3 shows the OCT images of sample. According to the refractive index measurement, calculus originates higher refractive index than other tooth tissues that result in stronger backscattering in OCT measurement. In clinical diagnosis, OCT image will provide a great help if the dental calculus region can be highlighted accurately. The measured image was post-processed with anisotropic diffusion filter, mid-value filter and threshold filter for noise suppression and identifies the position of calculus edge. [12] Figure 4 shows the processed subgingival calculus image and the calculus region is marked with red color.

Fig. 3 OCT image of subgingival calculus.

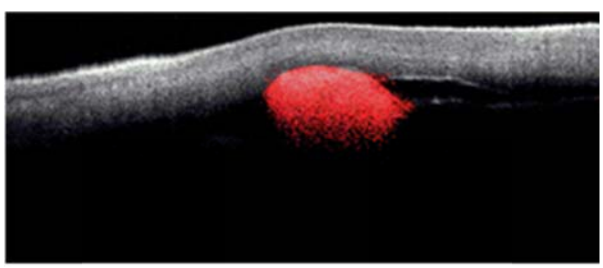


Fig. 4 Post-processed subgingival calculus image.

DISCUSSION AND CONCLUSION

We demonstrate a method not only for carious but also can be applied on subgingival calculus detection in dentistry. In clinical diagnosis, the method presents advantages compare to conventional X-ray imaging. X-ray imaging is radioactive and cannot observe the calculus on the proximal surface of tooth. However, OCT imaging can overcome the two drawbacks. The refractive index of tooth tissue as enamel, dentin, cementum and calculus are 1.625±0.024, 1.534±0.029, 1.570±0.021 and 1.896±0.085, respectively. Calculus reveals a strongly scattering property that originated with high refractive index. The dental calculus region then can be marked with post-process. SSOCT can be a great assistance for dental calculus detection.

Table 1: Refractive indices of dental tissues.

	Refractive index
enamel	1.625±0.024
dentin	1.534±0.029
cementum	1.570±0.021
calculus	1.896±0.094

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REFERENCES

[1] J. M. Poneros, S. Brand, B. E. Bouma, G. J. Tearney, C. C. Compton and N. S. Nishioka, "Diagnosis of specialized intestinal metaplasia by optical coherence tomography", *Gastroenterology*, vol. 120, issue 1, pp. 7~12, 2001.

[2] Y. Wang, B. A. Bower , J. A. Izatt, O. Tan and D. Huang, " Retinal blood flow measurement by circumpapillary Fourier domain Doppler optical coherence tomography", *Journal of Biomedical Optics*, vol.13, issue 6, 064003, 2008.

[3] A. Pagnoni , A. Knuettel , P. Welker , M. Rist , T. Stoudemayer , L. Kolbe , I. Sadiq and A. M. Kligman, " Optical coherence tomography in dermatology", *Skin Research and Technology*, vol. 5, issue 2, pp.83~87, 2006.

10. B. W. Colston, Jr., U. S. Sathyam, L. B. DaSilva, M. J. Everett, P. Stroeve and L. L. Otis, "Dental OCT", *Optics Express*, vol.3, no. 6, pp. 230~238, 1998.

[4] A. Baumgartner, S. Dichtl, C. K. Hitzenberger, H. Sattmann, B. Robl, A. Moritz, A.F. Fercher and W. Sperr, "Polarization-Sensitive Optical Coherence Tomography of Dental Structures", *Caries Research*, vol. 34, no.1, pp. 59~69, 2000.

[5] D. Fried , J. Xie, S. Shafi, J. D. B. Featherstone, T. M. Breunig, and C. Le, " Imaging caries lesions and lesion progression with polarization sensitive optical coherence tomography", *Journal of Biomedical Optics*, vol. 7, issue 4, 618, 2002.

[6] P. W. Smith, W. G. Jung, M. B., K. Osann, H. Beydoun, D. Messadi and Z. Chen. "In Vivo Optical Coherence

Tomography for the Diagnosis of Oral Malignancy", *Lasers in Surgery and Medicine*, vol.35, pp. 269~275, 2004.

[7] X. Xiang, M. G. Sowa, A. M. Iacopino, R. G. Maev, M. D. Hewko, A. Man, and K. Z. Liu, "An update on novel non-invasive approaches for periodontal diagnosis", *Journal of Periodontology*, vol. 81, no. 2, pp. 186~198, 2010.

[8] A. Hugoson, B. Sjödin, and O. Norderyd, "Trends over 30 years, 1973-2003, in the prevalence and severity of periodontal disease", *Journal of Clinical Periodontology*, vol. 35, no. 5, pp. 405~414, 2008.

[9] Y. S. Khader and Q. Ta'ani, "Periodontal diseases and the risk of preterm birth and low birth weight: a metaanalysis", *Journal of Periodontology*, vol. 76, no.2 pp. 161~165, 2005.

[10] D. M. Aeppli, J. R. Boen and C. L. Bandt, "Measuring and interpreting increases in probing depth and attachment loss", *Journal of Periodontology*, vol. 56, no. 5, pp. 262~264, 1985.

[11] G. J. Tearney, M. E. Brezinski, J. F. Southern, B. E. Bouma, M. R. Hee, and J. G. Fujimoto, "Determination of the refractive index of highly scattering human tissue by optical coherence tomography", *Optics Express*, vol. 20, issue 21, pp. 2258~2260, 1995.

[12] M. H. Le, C. L. Darling, and D. Fried, "Automated analysis of lesion depth and integrated reflectivity in PSOCT scan of tooth demineralization", *Lasers in Surgery and Medicine*, vol. 42, issue 3, pp. 62~68, 2010