The 1st International Symposium and Mini-Exhibition
Optical Coherence Tomography in Dentistry
Date: June 20-21, 2013
Place: TMDU Faculty of Dentistry Auditorium, 4th floor

Day 1- June 20, 2013 (Thursday)

Time	Subject	Speaker/Remarks
09:00-10:00	Poster and Exhibition Setup, Registration Open	
10:00-10:45	Keynote Address and Welcome Message	Junji Tagami
10:45-11:30	Imaging Tooth Demineralization and Remineralization with Polarization Sensitive OCT	Daniel Fried
11:30-12:15	Expanding the Domain of Optical Coherence Tomography in Dentistry	Robert Jones
12:15-13:00	Exhibition and Poster Viewing (Lunch Break)	
13:00-13:45	Development of a New Oral Diagnostic Tool using OCT	Yasunori Sumi
13:45-14:15	SS-OCT for the Detection of Dental Caries and Tooth Crack	Yasushi Shimada
14:15-14:45	Time-resolved and Quantitative Analysis of Dental Structures by OCT	Alireza Sadr
14:45-15:30	Exhibition and Poster Viewing (Coffee Break)	
15:30-16:30	Industry Presentations	Representatives
16:00-16:30	Group Discussions	
18:00-20:00	Dinner Reception	Invitation Only

Poster Presentations

No.	Title	Presenter
101	Optical and Nano-indentation Mechanical Properties Evaluation of Enamel Coated by Resin-thin-film	Ehab Alsayed
102	Non-destructive Assessment of Current One-step Self-etch Dental Adhesives using Optical Coherence Tomography	Baba Bista
103	Comparison of Optical Coherence Tomography versus micro-CT for visual assessment of early enamel lesions	Jorge Espigares
104	Assessment of Non-carious Cervical Lesions using Optical Coherence Tomography	Ikumi Wada
105	Characterization of Transparent Dentin in Attrited Teeth using Optical Coherence Tomography and Nanoindentation	Mona Mandurah
106	Sealing performance of resin cements monitored using optical coherence tomography	Alaa Turkistani
107	Assessment of remaining dentin thickness during caries excavation by SS-OCT	Patrycja Majkut

Day 2- June 21, 2013 (Friday)

Time	Subject	Speaker
9:00-10:00	Registration Open	
10:00-10:30	Near Infrared Imaging of Dental Decay	Cynthia Darling
10:30-11:00	Assessment of Early Enamel Erosion with OCT	Hooi Pin Chew
11:00-11:15	Coffee Break (Poster Viewing)	
11:15-12:00	Early Dental Caries Assessment with Optical Coherence Tomography and Polarized Raman Spectroscopy	Lin-P'ing Choo-Smith
12:00-12:30	Laboratorial Method Proposal to Obtain Caries-affected Dentin Observed by OCT	Adriana Bona Matos
12:30-13:15	Lunch Break	
13:15-13:35	A Brief Review on Quantitative Diagnosis Technologies for Early Carious Lesions	Syozi Nakashima
13:35-13:50	Marginal Adaptation of Self-etch Adhesives by 3D Optical Coherence Tomography	Patricia Makishi
13:50-14:05	Estimation of the Enamel and Dentin Mineral Content from the Refractive Index	Ilnaz Hariri
14:05-14:20	Relationship between OCT image, Microscopic Gap and Bond Strength of Composites	Turki Bakhsh
14:20-14:35	Assessment of Tooth Fracture using SS-OCT	Yukie Nakajima
14:35-14:45	Closing	

Symposium Chair
Day 1- 10:00-10:45

Keynote Address and Welcome Message

Junji Tagami
Professor, Cariology and Operative Dentistry
Dean, Faculty of Dentistry
Tokyo Medical and Dental University

Welcome Message

Optical coherence tomography is (OCT), is an emerging technology that can provide tomographic images of the tissue without using X-ray. This non-invasive imaging modality has a promising prospect for dentistry. It is an honor for us to have leading researchers in the field of OCT from home and abroad to discuss the applications of this technology for various purposes including non-destructive monitoring of oral structures and related topics in this symposium. Cariology and Operative Dentistry, TMDU has played a leading role in various important achievements in the dental field with a focus on minimally invasive dentistry. Most recently, we have been involved in the development of SS-OCT intra-oral probe for dental application with the collaboration from the industry and Ministry of Health and published several papers in the past 5 years on the great potentials of this amazing modality in our field. Researchers, students, clinicians and entrepreneurs are cordially invited to attend this symposium, which is held in the most central national dental school in Japan, and share the excitement of the next stage of adopting OCT in dentistry.

Biography

Prof. Junji Tagami received his DDS degree at the Faculty of Dentistry, Tokyo Medical and Dental University in 1980. He obtained his Ph.D. degree under the supervision of Profs. Takao Fusayama and Hiroyasu Hosoda in Dental Science in March 1984. In 1987 and 1988, he studied under Professor David Pashley, Medical College of Georgia. Currently, Dr. Tagami is Dean of the Faculty of Dentistry. His primary research interest involves studies related to the adhesion of restorative materials to tooth substance and dental materials within the broad area of adhesive dentistry, and the cariology. He has led the OCT project at Tokyo Medical and Dental University with a vision to promote this technology in Japan and globally as a tool for clinical dentistry. His research works have been published in more than 300 international and national peer-reviewed journals.

Invited Speaker
Day 1- 10:45-11:30

Imaging Tooth Demineralization and Remineralization with Polarization Sensitive Optical Coherence Tomography

Daniel Fried
Professor
Preventive & Restorative Dental Sciences
University of California, San Francisco, USA

Abstract

New methods are needed for the nondestructive measurement of tooth demineralization and remineralization, to monitor the progression of incipient caries lesions and assess lesion activity. If caries lesions are detected early enough they can be arrested by chemical intervention and dietary changes without the need for surgical intervention. Optical coherence tomography is ideally suited to monitor the changes that occur in caries lesions, since it can nondestructively image the internal structure of the lesion with an axial resolution exceeding 10-μm. Lesions can become arrested due to the preferential deposition of mineral in the outer surface zone of the lesion. The deposition creates a highly mineralized and weakly scattering surface zone that is clearly discernable in OCT images. Since this zone is near the highly reflective tooth surface, cross-polarization OCT imaging can greatly facilitate resolution of this zone.   The contrast of demineralization is also increased in the cross polarization OCT images. In this presentation, the results of *in vitro* OCT imaging studies employing different demineralization and remineralization regimens that produce lesions with varying mineral gradients will be discussed. Automated algorithms were developed to assess the lesion depth and severity, even with highly variable mineral gradients in the lesions. The results of recent *in vivo* imaging studies on natural occlusal lesions, the development of early lesions, and remineralization of lesions with fluoride will also be presented.   This work is supported by research grant R01-DE17869 from the NIH/NIDCR.

Biography

Dr. Daniel Fried is a professor in the Division of Biomaterials and Bioengineering in the Department of Preventive and Restorative Dental Sciences at the University of California, San Francisco School of Dentistry. He received his PhD in Physical Chemistry from Wayne State University in 1992 and his thesis work involved laser ablation and spectroscopy. Dr. Fried has been a researcher in the field of laser dentistry for the past 20 years and he has published more than 180 research publications in this field. His work has included: fundamental measurements of the optical properties of dental hard tissues from the UV to the IR, studies of the interaction of carbon dioxide lasers with dental hard tissues for laser ablation of caries and the surface modification of enamel for caries prevention, the use of lasers for the selective removal of caries and composite restorative materials, the assessment of demineralization and remineralization with polarization sensitive optical coherence tomography, and the development of near-IR imaging for caries detection. He is an editor of Journal of Biomedical Optics and SPIE conference proceedings Lasers in Dentistry.

Invited Speaker
Day 1- 11:30-12:15

Expanding the Domain of Optical Coherence Tomography in Dentistry

Robert Jones
Assistant Professor
Division of Pediatric Dentistry
University of Minnesota, USA

Abstract

In this presentation, several important 'expanded use' dental OCT applications will be discussed. The main focus will be examining how cross polarization OCT can be a useful modality to further understand the process of secondary caries.   Clinical investigation of composite resin restorations will be discussed with an emphasis on the need to sample and study biofilms associated with restorations in various stages of health and disease. Several examples from studies examining biofilm growth will be presented including a key validation study.   The influence of composite formulations for OCT diagnostic imaging will also be presented.   Lastly, this presentation will also discuss the challenges associated with using OCT for CAD/CAM fabrication.

Biography

Dr. Jones received his DDS and PhD after completing the Dental Scientist Training Program at University of California, San Francisco. This NIH sponsored T32 training program gave Dr. Jones a graduate education in medical and optical biomedical imaging. His PhD was completed under the mentorship of Dr. Daniel Fried, whose research career has focused on lasers and optical imaging in dentistry. He completed his Pediatric Dental Residency at UCSF in 2009 and has done research in examining biological factors in Early Childhood Caries. Dr. Jones joined pediatric dentistry faculty and collaborative research environment at the University of Minnesota in 2009. Dr. Jones is a 2010 recipient of the Faculty Development Award from the 3M Foundation. He is also a Co-PI on a funded NIH grant (Sept 2010) examining the interaction of oral biofilms and dental resin composites. He is a pioneer of dental OCT with numerous key publications on the basics and applications of the technology. His current research interests include early caries detection using near infrared based imaging, e.g. OCT, and assessing risk factors in early childhood caries.

Invited Speaker
Day 1- 13:00-13:45

Development of a New Oral Diagnostic Tool using Optical Coherence Tomography

Yasunori Sumi
Professor and Director
Department for Advanced Dental Research
Center of Advanced Medicine for Dental and Oral Diseases
National Center for Geriatrics and Gerontology, Japan

Abstract

Optical coherence tomography (OCT) is a new biomedical imaging modality which can generate high-resolution, cross-sectional images of microstructures in biological systems. One of the most attractive features of OCT is that it uses safe near-infrared light instead of hazardous ionizing radiation. Furthermore, resolution on the order of 10 micrometers can be obtained. The optical accessibility of clinically relevant structures in the oral cavity makes it a particularly attractive location for the application of OCT imaging techniques. Our National Center for Geriatrics and Gerontology has developed a new swept-source optical coherence tomography (SS-OCT) system by industry and public-sector joint research. This new SS-OCT system was applied for cross-sectional imaging of dental caries, resin based composite restorations, periodontal disease, oral cancer and finished dentures in this review. It is concluded that our new SS-OCT system is a promising new and useful alternative imaging technique which can safely provide much more definitive information on oral structures at far higher resolution than possible by conventional clinical imaging methods. Our National Center for Geriatrics and Gerontology has this new dental SS-OCT system of Japanese origin into the world's first production.

Biography

Dr. Sumi received his DDS from TMDU in 1981 and completed post-graduate course in oral surgery at Nagoya University in 1985. His primary research interest has focused on oral care for the elderly. He is the pioneer of development of dental OCT in Japan, and has worked with a number of co-investigators in the OCT project funded by Research Grant for Longevity Sciences from Ministry of Health, Labor and Welfare. Under his direction, dental SS-OCT system has been developed at National Center for Geriatrics and Gerontology of Japan. He holds several international patents related to dental OCT imaging. Dr. Sumi is also the editor-in-chief of Journal of the Japanese Society of Gerodontology and serves on the editorial board of Geriatrics & Gerontology International.

TMDU Speaker
Day 1- 13:45-14:15

SS-OCT for the Detection of Dental Caries and Tooth Crack

Yasushi Shimada
Cariology and Operative Dentistry
Department of Oral Health Sciences
Tokyo Medical and Dental University

Abstract

Caries diagnosis: The diagnosis of dental caries of posterior teeth is a challenge due to the restricted access for examination. Despite the dramatic decline of caries incidence, the disease is far from eradicated, particularly in children and young adults. The occlusal fissures of the first permanent molars are generally the first sites in the permanent dentition to develop caries. Although it is well accepted that bitewing radiography provides additional benefits in the detection of occlusal caries and non-cavitated proximal lesions, evidence for their value in epidemiological studies is still controversial. Dental radiographs seem to exhibit low sensitivity, but rather high specificity, while the true extent of caries lesions seems to be underestimated when relying solely on radiographs. From our in vivo and in vitro studies, Swept Source OCT (SS-OCT) showed higher sensitivity and Az values of ROC analysis than the conventional caries detection method, especially for the detection of cavitated enamel lesions and dentin caries. Tooth crack diagnosis: Cracked teeth have been a diagnostic challenge for more than half century because of the difficulty in locating crack lines of incomplete tooth fracture. Most clinicians may not find the presence of crack until they encounter complicated and diverse symptoms associated with chewing and cold. Longitudinal tooth fractures have been categorized into 5 major classes: craze line, fractured cusp, cracked tooth, split tooth, and vertical root fracture. Since a crack has an unpredictable prognosis including extraction, accurate diagnosis regarding the size and localization of the crack is required to determine the most appropriate treatment technique. SS-OCT was employed for the detection of naturally formed cracks and was capable of providing clear imaging of enamel cracks including information on penetration depth. Even when cracks extended beyond DEJ, OCT was capable of imaging the whole line, determining crack penetration depth.

Biography

Dr. Shimada is a senior faculty member of Cariology and Operative Dentistry. He studied dentistry and took his Ph.D. at the same institution. His extended research activities have involved characterization of dental adhesives, introducing new methodologies such as the wire-loop micro-shear bond strength test. Dr. Shimada has the experience of working at the National Institute of Standards and Technology (NIST), and has also been involved in research on pulp biological response. He is currently involved in the OCT research project with a focus on the clinical aspect, and development of an intra-oral imaging probe for chair-side imaging.

TMDU Speaker

Day 1- 14:15-14:45

Time-resolved and Quantitative Analysis of Dental Structures by Optical Coherence Tomography

Alireza Sadr

Cariology and Operative Dentistry
Department of Oral Health Sciences
Tokyo Medical and Dental University

Abstract

Swept source optical coherence tomography without polarization sensitivity has shown a unique capability for real-time imaging of dental structures, especially for time-resolved determination of defect formation. In the first part of this talk, we present our methodology for non-destructive evaluation of marginal and internal microgaps in three-dimensions as well as real-time imaging of gap formation during composite placement and polymerization. This methodology is based on the optical contrast between the media filling the defects and the composite resin or dental hard tissue which results in a detectable reflectivity signal peak. The development and evolution of this methodology has now enabled 3D visualization without the need for staining or dye penetration. Our new approach and its findings alone can establish OCT as an invaluable tool for dental materials research; however, there are still limitations that should not be over looked such as imaging depth and variations among composites. In the latter part of this talk, we introduce our latest clinical results on quantitative monitoring of enamel lesion remineralization based on OCT signal analysis. In the series of case presented, enamel white-spot lesions were detected in patients and monitored over time while the patients were exposed to increased levels of salivary Ca and F through daily consumption of a chewing gum (POs-Ca F). Successful healing of some lesions are evident from OCT images obtained as soon as one month after the treatment started; nevertheless, the degree of success was varied among different cases.

Biography

Dr. Sadr is a Junior Associate Professor at Cariology and Operative Dentistry, Department of Oral Health Sciences. He joined TMDU as a graduate student in 2003, received his Ph.D. as a Japanese government scholar under supervision of Prof. Tagami in 2008 and became a faculty member and principal investigator at the Global COE program in 2009. His field of research involves characterization of dental hard tissue and biomaterials. He is also enthusiastically working on the OCT development project with Ph.D. candidates and colleagues, investigating alternative methodologies for OCT image and signal analyses, monitoring dental lesions and defects. He has authored and coauthored over 80 full-length research publications with his colleagues at TMDU, and received funding for several research projects from the Japanese Society of Promotion of Science (JSPS) and Japanese Ministry of Education (MEXT). His research has brought him several domestic and international scientific awards including three consecutive outstanding research prizes in Adhesive Dentistry in 2011, 2012 and 2013.

Distinguished Speaker

Day 2- 10:00-10:30

NIR Imaging of Dental Decay

Cynthia Lee Darling
Associate Professor
Preventive & Restorative Dental Sciences
University of California, San Francisco, USA

Abstract

Near-Infrared (NIR) imaging is a new technology that is currently being investigated for the detection and assessment of dental caries. Recent *In vivo* and *in vitro* imaging studies have shown that high contrast images of tooth demineralization can be acquired in the NIR due to the high transparency of dental enamel and that the maximum contrast between sound and demineralized enamel lies in the 1300-1600-nm region. Therefore, this wavelength range is well suited for transillumination and reflectance imaging of dental caries. Images of the lesion can be acquired from the facial, lingual, and occlusal surfaces and from multiple angles for optimum viewing. Many of the chromophores responsible for stains do not absorb light in the NIR allowing for easier discrimination of carious lesions in occlusal surfaces. This method also has great potential for the examination of defects in tooth structure, and internal cracks in the enamel are visible due to the high transparency of the enamel in the NIR. Our recent clinical study showed that NIR imaging has great potential as a screening tool for the detection of occlusal and approximal lesions without the use of ionizing radiation (x-rays). Support: NIH Grant R01-DE14698.

Biography

Cynthia Lee Darling is an Associate Professor in the Division of Biomaterials and Bioengineering in the Department of Preventive and Restorative Dental Sciences at the University of California, San Francisco School of Dentistry. She received her PhD in Physical Chemistry from Wayne State University in 1993 in the area of theoretical quantum and classical mechanics. Dr. Darling has been a researcher in the field of biomedical photonics for the past eleven years and her contributions made to this field include development of a fully automated Mueller polarimetric imaging system to completely describe the interaction of polarized light with dental hard tissues. Dr. Darling and her research group have also investigated the optical properties of developmental defects, employed NIR imaging to monitor laser ablation through dental enamel in real-time to directly visualize peripheral thermal and mechanical damage, and explored the image contrast of dental caries at other NIR wavelengths besides 1300-nm.

Distinguished Speaker
Day 2- 11:15-12:00

Early Dental Caries Assessment with Optical Coherence Tomography and Polarized Raman Spectroscopy

Lin-P'ing Choo-Smith
Research Officer
National Research Council, Canada

Abstract

In recent years, we have been exploring the use of optical coherence tomography (OCT) and polarized Raman spectroscopy (PRS) as potential clinical tools for in vivo early dental caries assessment. The underlying basis is that OCT and PRS furnish complementary morphological depth imaging and biochemical specificity, respectively, to provide clinicians with an improved detection tool over conventional clinical methods. This presentation will describe our research results ranging from early laboratory bench studies on extract human tooth samples towards the development of portable and specialized OCT and PRS prototype systems and fibre-optic intra-oral probes for in vivo assessment with patient volunteers. The strengths, limitations and new insights from combining OCT and PRS for dental caries assessment will also be discussed.

Biography

Dr. Lin-P'ing Choo-Smith is a Research Officer in the Medical Devices Portfolio at the National Research Council Canada (NRC; Winnipeg, MB). She has a B.Sc. from the University of Toronto (1992), Ph.D. from the University of Manitoba (1996) and post-doctoral training at Case Western Reserve University (Cleveland, OH, USA; 1996-1997) and Erasmus University Rotterdam (Rotterdam, The Netherlands; 1997-2001). Her research interests include biomedical applications of Raman spectroscopy and applied photonics especially dental caries assessment. Since joining the NRC in 2001, she has been involved with developing the combination of optical coherence tomography and Raman spectroscopy for early dental caries detection and monitoring. This research involves dental clinical collaborators from the Faculty of Dentistry at the University of Manitoba and Dalhousie University. Dr. Choo-Smith is the principal investigator of a research team with funding over the years through NRC and grants from the Canadian Institutes of Health Research and US National Institutes of Health.

Oral Presentation
Day 2- 10:30-11:00

Assessment of Early Enamel Erosion with OCT

Hooi Pin Chew
Dept. of Restorative Dentistry
University of Malaya, Malaysia

Abstract

The goal of the studies undertaken and was to seek a detection tool that could be used in clinical trials to evaluate the efficacy of interventions meant to reduce the rate of dental erosion. It is almost futile to endeavour on clinical trials that involve subjects with existing wear lesions as the aetiology is multifactorial with one of the wear process being more predominant than the other. The challenges facing such clinical trial are the illusiveness of the clinical presentation of erosive wear and the lack of an objective tool to detect erosive wear lesions. An alternative approach would be to induce dental erosion. This study design eliminates ambiguity and produces more uniform level of erosion. However if erosion was to be induced intra-orally ethically, a detection tool that is sensitive to the very early stages of erosion before the occurrence of surface loss is crucial. *In vitro* studies followed by *in situ* studies were carried out. The objective of the *in vitro* studies were to lay down the ground work of identifying the strengths, limitations and detection threshold of OCT and the study designs aimed at simulating as closely as possible a clinical situation, one that is transferable to a future *in situ* or *in vivo* study. The degree of demineralisation induced was small, only involving surface-softening, with no evidence of surface loss or step change of more than 10 microns so that it is ethically viable to reproduce in a clinical trial. A new algorithm for OCT backscattered intensity was explored and used in these studies. A double-blind *in situ* study was then carried out on healthy participants wearing appliance that were embedded with human enamel samples. The primary objective of the study was to evaluate the sensitivity of OCT in the detection of early enamel erosion in an *in situ* setting. However, besides the validation of both optical techniques, two secondary objectives were included in the study. They were to evaluate the difference of response to acid challenge between natural-surface and polished surface enamel and to evaluate whether a pre-exposure period to the oral environment affected the rate of erosion.

Oral Presentation
Day 2- 12:00-12:30

Laboratorial Method Proposal to Obtain Caries-affected Dentin Observed by OCT

Adriana Bona Matos

Professor
Operative Dentistry
University of São Paulo, Brazil

Abstract

The aim of this in vitro study was to validate a protocol for obtaining standard caries affected-dentine by dentine demineralization process induced by Streptoccocus mutans biofilm. Validation methods performed were optical coherence tomography (OCT), visual inspection, laser fluorescence and digital radiography. Total of 48 human molars (24 erupted and 24 unerupted) were grounded in the occlusal surface to remove enamel and obtain a flat dentin surface. The specimens were cut in the bucco-lingual direction yielding two fragments that were randomized into experimental groups. The dental fragments were protected with acid resistant varnish in half of the occlusal surface (control) and in the other half was produced carious lesions. The experimental groups were composed from two variation factors: period of cariogenic challenge (7, 14 and 21 days) and type of dentin (from erupted or unerupted teeth). Thus six experimental groups were formed: with dentin from erupted teeth (ET) - G1 (7 days of cariogenic challenge), G2 (14 days), G3 (21 days), and with dentin from unerupted teeth (UT) - G4 (7 days), G5 (14 days) and G6 (21 days). After different periods of cariogenic challenge, the specimens were evaluated on their healthy and caries-affected portions using different diagnostic methods and the results were compared. Visual inspection proved the formation of caries affected dentin as characteristics of the tissue as yellowing, loss of surface gloss and consistency elastic were observed. The digital radiography was able to detect the presence of radiolucent image, suggesting caries. Three calibrated examiners viewed all the images obtained by visual inspection and digital radiography, and were able to distinguish healthy from caries affected dentin. We used the Fisher exact statistical test with a significance level of 5% which confirmed no difference between groups in both visual inspection (G1 and G4 - p=0.6; G2 and G5 - p=1 and G3 and G6 - p=1) and digital radiography (G1 and G4 - p=1, G2 and G5 - p=1 and G3 and G6 - p=1). Both laser fluorescence values and depth of demineralization (OCT) were subjected to statistical test Analysis of Variance (ANOVA) (p<0.05). Regarding the values obtained by laser fluorescence, a statistically significant difference can be observed for the factor type of substrate (p=0.001), with the erupted teeth specimens with higher fluorescence compared to specimens from UT. For OCT, we can observe that there was no statistically significant difference for the factor type of substrate (p=0.163), for the factor length of cariogenic challenge (p=0.512) and interaction between factors (p=0.148). Finally, photomicrographs were obtained by scanning electron microscopy which confirmed the presence of caries affected tissue produced artificially at all demineralization times tested, however a more uniform demineralization surface was observed in caries affected dentin of UT. Thus, we conclude that 7 days of cariogenic challenge is sufficient to obtain standard caries affected dentin to be used in laboratory tests and UT provided a more suitable substrate for use in this proposed protocol.

Oral Presentation

Day 2- 13:15-13:35

A Brief Review on Quantitative Diagnosis Technologies for Early Carious Lesion

Syozi Nakashima

Cariology and Operative Dentistry
Department of Oral Health Sciences
Tokyo Medical and Dental University

Abstract

Each of the caries diagnostic technologies mentioned below has different advantages and limitations in clinical use. Present review will focus mainly on the principles of how to detect and quantify the carious lesion. **Diagnodent**[TM] detects fluorescence originating from porphyrin produced by bacteria metabolism in carious lesion; **QLF**[TM] (Quantitative Light-induced Fluorescence) detects difference in fluorescence intensity originating from unidentified organic or inorganic materials in tooth tissues; **ECM** (Electric Caries Meter or Electric Conductivity Measurement) detects electric conductivity in demineralized porous tooth tissues; **FOTI** (Fiber Optic Trans-Illumination) uses endoscope to capture the lesion image based on reflectivity difference in lesion; **Cariotester**[TM], very recently introduced in Japanese market, measures the hardness or indentation depth at the lesion surface; **thermographic device** (not commercially available) measures the rate of heat dispersion at demineralized tooth surface layer after millisecond heating by a xenon flash lamp. Present review explains Diagnodent[TM], QLF[TM], thermographic device, and Cariotester[TM]. These technologies are compared to OCT technology in terms of the caries detection mechanism occurring in de- and remineralized lesion, with emphasizing that these technologies are constructed based on porosity change in tooth tissues caused by de- and remineralization.

Oral Presentation
Day 2- 13:35-13:50
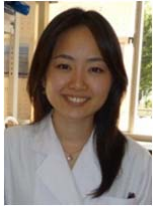
Marginal adaptation of self-etch adhesives by 3D OCT

Patricia Makishi

Dental Materials
Department of Restorative Dentistry
Piracicaba Dental School
State University of Campinas, São Paulo, Brazil

Abstract

Objectives: To investigate the potential use of swept-source optical coherence tomography (SS-OCT) as a tool to evaluate marginal adaptation of composite restorations in class I cavities.   Methods: Round-shaped class I cavities (3mm diameter x 1.5mm depth) were prepared on buccal enamel of bovine teeth with cavity floor located in dentin. The cavities were restored with a flowable resin composite (Clearfil Majesty LV) using two-step self-etch adhesive (SE Bond), all-in-one self-etch adhesive (G-Bond) or no adhesive (Control). The specimens were subjected to water storage (37°C, 24 h) or thermal stress challenge (5,000 cycles, 5°C and 55°C). 3D scans (4mm x 4mm x 2.6mm scanned and processed in 4 s) of the restoration were obtained using SS-OCT before and after immersion into a contrast agent. 2D images obtained from the 3D scans (n=30/group) were analyzed to evaluate marginal adaptation. Area fraction of pixels with high brightness values at the interfacial zone was calculated using a digital image analysis software. The result was statistically compared with statistical significance defined as $p \leq 0.05$.   Results: Wilcoxon signed ranks test found no statistically significant difference in the results of SS-OCT between non-stained and stained specimens when a ranking transformation was applied on to the data ($p > 0.05$). A significant positive linear correlation was found between SS-OCT stained and non-stained samples. Confocal laser scanning photomicrographs of samples cut after staining confirmed the presence of gap.   Conclusions: 3D imaging by SS-OCT can be considered as a non-invasive technique for fast observation of marginal integrity at the tooth-restoration interface.

Oral Presentation
Day 2- 13:50-14:05

Estimation of the Enamel and Dentin Mineral Content from the Refractive Index

Ilnaz Hariri

Cariology and Operative Dentistry
Department of Oral Health Sciences
Tokyo Medical and Dental University

Abstract

Objective: Recent advances in the optics have enabled accurate and localized measurement of optical properties of biological substrates. Interferometric measurement of optical path-length is a promising approach to characterize biomaterials. This work aimed to elucidate the relationship between local refractive index (n) and mineral content (MC) of enamel and dentin.

Material and Method: De- and remineralized lesions in bovine enamel and dentin blocks were sectioned into 300-400 µm-thick slices, and placed on a metal plate to capture images of sound, de- and remineralized regions transversely by optical coherence tomography (OCT). Mean n at each depth level of the lesion (20-µm or 40-µm step for enamel or dentin) was measured by optical path-length matching method, and used to plot n through lesion depth. The specimens were further polished and processed for transverse-microradiography for analysis of MC. Results: The n and MC ranged 1.52-1.63 and 50-87 (vol.%) in enamel, and 1.43–1.57 and 11–48 (vol.%) in dentin, respectively. Strong, positive linear correlations were found between n and MC (Pearson's r = 0.95 and 0.91 for de- and remineralized enamel, and r = 0.94 and 0.91 for dentin respectively, p<0.001). The experimental data were validated with a theoretical calculation of n from MC. Conclusion: De- and remineralization of enamel and dentin resulted in measurable changes of n, and in turn, MC changes of the tissue could be estimated with good accuracy from this long-known optical property by the new analytical approach. Compositional changes of enamel crystallites after remineralization affect n.

Oral Presentation
Day 2- 14: 05-14:20

Relationship between OCT image, Microscopic Gap and Bond Strength of Composites

Turki A. Bakhsh
Cariology and Operative Dentistry
Department of Oral Health Sciences
Tokyo Medical and Dental University

Abstract

This study investigated class-I cavity floor adaptation by swept-source optical coherence tomography (SS-OCT) in combination with microtensile bond strength (MTBS) using different filling methods. Method: Two adhesive systems; Tokuyama Bond Force and Tri-S Bond Plus were used in conjunction with a universal composite (Estelite Sigma Quick) placed either incrementally (oblique) or in bulk with or without a flowable composite lining (Palfique Estelite LV). Ten serial B-scan images were obtained throughout each cavity by SS-OCT (center wavelength: 1319 nm). In order to evaluate adaptation defined as the cavity floor percentage showing no gap, a significant increase in the signal intensity was considered as gap at the bonded interface of the cavity floor. The same specimens were then cut into beams to measure MTBS at the cavity floor. Results: Two-way ANOVA demonstrated that the interaction of adhesive systems and filling techniques was significantly affecting both adaptation and MTBS ($p < 0.05$). There was a significant correlation between MTBS and adaptation at cavity floor ($p < 0.05$). Cavity floor adaptation and MTBS were improved when incremental filling technique was applied, while the outcome of lining technique was variable. Conclusions: Quantitative assessment by SS-OCT can non-destructively provide information on the performance and effectiveness of dental composites and restoration techniques. There was a moderate correlation between floor adaptation and bond strength in class-I cavities. Incremental application of composite restoration was the most advantageous placement technique in terms of bond strength and internal adaptation.

Oral Presentation
Day 2- 14: 20-14:35

Assessment of Tooth fracture using SS-OCT

Yukie Nakajima

Pediatric Dentistry
Department of Oral Health Sciences
Tokyo Medical and Dental University

Abstract

Tooth fractures may in severity from the minimal enamel crack to a complete longitudinal fracture, both of which have been considered to be a common clinical problem. The aim of this study was to investigate the ability to detect cracks as well as the effect of scanning angle in SS-OCT compared with histological sections. Material & Method: Cracks were created by subjecting 30 porcine premolars to impaction by a steel rod plunging from the occlusal tip. SS-OCT images and stereomicroscopic photographs of the surface were acquired for each specimen before and after impaction. For evaluation, the focused light beam of SS-OCT was projected from 3 directions on the same plane: buccal or lingual, 45° to the mesial,   and 45° to the distal. Histological sections were prepared after impaction, and length and width of cracks were evaluated using the corresponding SS-OCT image.   Results: Through SS-OCT, cracks were clearly detected as intensified scattering signals at the same position on the corresponding microphotographs and histological sections. Among the 3 scanning angles, the greatest lengths and widths were considered the corresponding values of SS-OCT and were used for analysis. Significant correlations regarding line length and width were observed between SS-OCT and histological sections (length: $r = 0.65$, $p < 0.001$; width: $r = 0.60$, $p < 0.001$). Conclusions: SS-OCT can clearly discriminate cracks, which appear as highlighted lines due to the scattering of light. The results obtained from the 3 scanning directions were correlated well with those of the histological sections.

Poster Presentation
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Optical and Nano-indentation Mechanical Properties Evaluation of Enamel Coated by Resin-thin-film

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Abstract

The aim of this study was to investigate the durability of enamel coating materials and their effects against demineralization using Swept Source Optical Coherence Tomography (SS-OCT). Methods: Forty blocks were prepared from bovine incisors. The enamel surfaces of the blocks embedded in epoxy resin. The embedded samples were assigned to different groups (n = 10) as follow: (1): resin based coating material (RBCM) shield force plus (Tokuyama Dental, Tokyo, Japan), (2): RBCM Protect Bond (Kuraray Medical, Tokyo, Japan), (3): RBCM PRG Barrier Coat (Shofu, Kyoto, Japan), (4): RBCM Varnish XT (3M/ESPE, St. Paul, MN, USA). 2D scans for each specimen obtained using SS-OCT (1319 nm wavelength, Panasonic Healthcare, Japan). The specimens were subjected to 5000 thermocycling and OCT images were captured after thermocycling challenge. Then the coated specimens will be exposed to demineralization for 1 day, 4 days and 7 days in a demineralization solution (pH 4.5) at 37°C. SS-OCT images were taken after demineralization procedure. The specimens were embedded in rigolac resin then cross-sectioned and subjected to nanoindentation to confirm OCT results. Nano-indentation hardness of the coated and uncoated enamel surface were measured under 2mN load with 1s hold segment, up to 200 um depth. Conclusion: A sealed enamel surface by thin resin coatings containing active ingredients such as fluoride will remarkably contribute to the protection of smooth enamel surface from erosive acid challenge. While very thin layers (<10 μm) are not clearly detected under OCT, the modality can be used to monitor enamel changes beneath these protective coatings. Significance: Achievement of sealed enamel surface by thin resin coatings containing active ingredients such as fluoride will contribute to the whole concept of "super tooth" and practice of restorative dentistry.

Poster Presentation
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Non-destructive Assessment of Current One-step Self-etch Dental Adhesives using Optical Coherence Tomography

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Abstract

This study aimed to non-destructively evaluate sealing performance of 8 one-step self-etch adhesives (1-SEAs) using optical coherence tomography (OCT). The two-step self-etch adhesive (2-SEA) served as the control. Round tapered class-I cavities (D=4mm, H=2mm) were prepared in bovine incisors, treated with each adhesive (n=5), and restored with a flowable resin composite. Cross-sections were obtained from each restoration using swept-source OCT with 1310 nm laser. The average percentage of the sealed interface (SI%) for each adhesive was calculated using an image analysis software, considering increased signal intensity at the interface as gap. Samples were then sectioned and observed under confocal laser scanning microscope (CLSM). Significantly different SI% values were found among different adhesives (ANOVA, Bonferroni, $p<0.05$). There was also a significant correlation in SI% between OCT and CLSM ($p<0.0001$, r=0.96). Some recent 1-SEAs could achieve reliable short-term sealing comparable to 2-SEA. OCT is a unique tool to non-destructively evaluate the sealing performance of the restoratives through the cavity, provided that cavity walls have a certain minimum inclination with respect to the beam.

Poster Presentation
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Comparison of Optical Coherence Tomography versus Micro-CT for Assessment of Early Enamel Lesions

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Abstract

Dentists need a technology that can non-invasively and reliably quantify hidden or sub-surface caries, and its progression. Dental radiographs do not have the sensitivity for early carious lesions. Optical Coherence Tomography (OCT) is a new non-invasive and non-destructive diagnostic methods that can provide us high-resolution cross-sectional images. The aim of this study is to compare the Optical Coherence Tomography with Microfocus X-ray Computed Tomography (μCT) in terms of early enamel lesion visualization. METHOD AND MATERIALS: 16 human teeth with visible white-spot like changes on enamel smooth surface with no cavitation were selected. The cross-section of interest was marked using two guiding holes at the sides of the lesion created by Er:YAG laser (Erwin AdvErl , MORITA). The samples were then subjected to OCT imaging (Dental OCT Prototype II, Panasonic Health Care) and μCT (SMX-100CT, Shimadzu). The cross-section of interest was visualized in the imaging software from the 3D data stack of OCT and μCT following the guiding holes, and the OCT and μCT images were compared. RESULTS: In the OCT images, the lesions appeared as areas of increased signal intensity beneath the surface up to a certain depth, while in μCT, the demineralized areas appeared as radiolucency. Interestingly, these areas closely matched the high scattering areas of OCT image. Inspecting the resulting images from OCT and μCT, we could confirm sub-surface lesions with both systems and determine their shape and depth. CONCLUSIONS: OCT is a promising technology for clinical assessment of natural subsurface lesions, which can provide comparable images to a laboratory high-resolution μCT without the use of X-ray.

Poster Presentation
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Assessment of Non-carious Cervical Lesions using Optical Coherence Tomography

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Abstract

Non-carious cervical lesions (NCCL) involve various forms of tooth loss with different etiologies, which should be studied to enable prevention and proper treatment. The objectives of this study were to evaluate the correlation among the NCCL dimensions, cervical crack extent and amount of occlusal attrition, determined by swept-source optical coherence tomography (SS-OCT).Methods: Ninety extracted human teeth with NCCL were used. Cross-sectional images of NCCL were obtained by SS-OCT to measure the depth (D: μm) and axial length (L: μm) of NCCL using image software (Image J). The morphology of NCCL was characterized by D×L size parameter. Cervical crack along DEJ and the remaining enamel thickness (RET) under the occlusal or incisal attrition surface were also evaluated using SS-OCT. The teeth were then sectioned and directly observed using confocal laser microscope to confirm the presence of cracks. Relationships between D×L, crack, and RET were evaluated by Pearson's correlation at significance level of $\alpha = 0.05$. Results: Cross-sectional views of NCCLs were readily obtained by SS-OCT for morphological assessment in real time. In the grayscale SS-OCT images, cracks were detected as highlighted bright lines, since the signal intensity increased at the crack borders. Significant correlations were detected between crack length and RET; with attrition resulting in small RET, more extensive cervical cracks were found. There were no statistical correlation between crack length and D×L, and D×L and RET; however when D×L was limited up to 0.4 mm², statistical correlation was found with RET; larger NCCLs were found in tooth with small RET. Conclusion: SS-OCT showed the potential to obtain the cross-sectional images for studying the structural morphology of NCCL and enamel crack noninvasively. The results of the current study showed the possible association of enamel attrition and NCCL formation.

Poster Presentation
105

Characterization of Transparent Dentin in Attrited Teeth using Optical Coherence Tomography and Nanoindentation

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Abstract

Attrition of tooth surface is a problem with physiologic aging of teeth resulting in histological changes in dentin and surrounded tissues; the main objective of this study is to characterize the sclerotic or transparent dentin of attrited teeth in the occlusal surface, optically by the use of Swept Source Optical Coherence Tomography (SS-OCT) and mechanically by using nanoindentation. Human teeth were used in this study; naturally attritioned teeth with occlusal sclerotic surfaces, sound teeth, and carious teeth. All these teeth were subjected to SS-OCT for optical evaluation , then were cut to be observed under, light microscopy and CLSM , after that, mechanical evaluation were done under nanoindentation. There were some changes observed with OCT in the superficial layer of transparent dentin compared to control group in the same area, these changes appeared as increase in the backscattered light of sclerotic dentin. The mean values of attenuation coefficient μ_t were 1.05 mm^{-1}±0.3, 2.23 mm^{-1} ±0.4 and 0.61 mm^{-1}±0.27 for Sound, Carious and Transparent dentin respectively. Transparent dentin recorded the lowest value compared to Sound and Carious dentin. SS-OCT has a potential role to diagnose sclerotic transparent dentin in the superficial layer and it can be used in the future as diagnostic tool to detect any abnormalities in teeth.

Poster Presentation
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Monitoring Sealing Performance of Resin Cements Using Optical Coherence Tomography

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Abstract

Optical coherence tomography (OCT) is a non-invasive diagnostic imaging technique that can give real time, high resolution images using a safe broadband light source. It has shown a promising utility for in-depth imaging of direct composite restorations without cutting the sample or using ionizing radiations. Also, it is a subjective method that allows interpretation of the same section several times. In this in vitro study, swept-source OCT (Santec) at 1310 nm center wavelength was used for monitoring adaptation of indirect resin restorations after aging. Resin inlays were luted to class-I cavities of extracted human teeth using three resin cements; Clearfil SA Luting (SA; Kuraray), Bistite II DC or Multibond II (Tokuyama Dental). Each cement was applied with or without pre-coating of dentin by a self-etch adhesive and a flowable composite. 3D OCT imaging was performed after 24h, after 2,000 or 10,000 thermocycles (n=5). Selected samples were sectioned for interfacial observation by confocal laser scanning microscope (CLSM). Floor adaptation (percentage) was analyzed by (custom-code) software on 20 B-scans throughout each specimen, and subjected to statistical analysis. Resin cement type, resin coating and thermal aging all significantly affected adaptation (p<0.05). The best results for all cements were consistently achieved when resin coating technique was applied. CLSM closely confirmed OCT findings in all groups. It was concluded that OCT could be used for monitoring of composite inlays with several interfacial resin layers during aging as a non-destructive test method.

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Assessment of Remaining Dentin Thickness during Caries Excavation by SS-OCT

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Abstract

Objectives: This study was carried out to evaluate the efficacy of Dental SS-OCT in visualizing the remaining dentin thickness during excavation of deep dentine caries. Materials and methods: In this pilot study human molars with deep dentine caries were selected. The most superficial soft debris was removed with spoon excavator. Roots were flattened parallel to the occlusal surface during OCT scanning at 1330 nm center wavelength (Dental SS-OCT Panasonic, Japan) 3D OCT scans were obtained before and after the application of Caries Check (Nishika, Japan). Some 2D OCT scans were taken at selected regions of the sample after the removal of caries portion as indicated by dye detector with micro-motor . Pulpal horns and pulp chamber were observed. Afterwards specimens were sectioned using diamond saw (Isomet, Buehler, USA) with water lubrication at the same sections which were observed under OCT. Specimens were not grind intentionally to mimic the clinical situation. The sections were polished using wet no.2000 grid silicon-carbide paper and diamond pastes with particles downsized from 6μm up to 1μm respectively. All specimens were ultrasonicated. CLSM (Lasertec) images were taken at magnification level of 5x to confirm and compare the remaining dentin thickness measurements between SS-OCT and CLSM. Thickness measurement of the RDT was done on samples section by image analysis software (ImageJ version 1.45). From each image RDT was measured at 5 regions and average value was calculated. For the confirmation of OCT findings CLSM images were taken at the same cross-section that was observed under OCT.   Results: OCT findings were confirmed by CLSM observation. The remaining dentine thickness (RDT) visualized under OCT corresponded to those of CLSM considering the refractive index of dentine (n=1.55). Nevertheless, in case of infected dentin, it was difficult to determined strong attenuation through the carious dentine. Conclusion: This study was a trial to visualize RDT over the pulp chamber using SS-OCT and it was found that it is possible to use SS-OCT during deep caries excavation for the prevention of perforation of the vital dental pulp. OCT with near infrared light can act as a reliable tool to visualize the RDT because of the optical contrast between the dentine and the pulp. Further study will be done by using simulated pulpal fluid followed by confirmatory tests using X-ray microfocus computed tomography.