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Biomimetic Tizian "table tops" analyzed with swept source optical coherence tomography

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ABSTRACT

"Table tops"/occlusal veneers are partial crowns that allow for the biomimetic restoration of worn teeth in bruxing patients. The biomimetic approach includes a **CAD/CAM** composite resin for the manufacturing of the "table tops", for example Tizian, which is a zirconia reinforced composite (Schutz Dental Group). In the present study we prove the value of a fast swept source optical coherence tomography (**SS-OCT)** system in the evaluation of the marginal fit of Tizian "table tops". 12 maxillary first premolars were extracted and minimally invasive prepared for "table tops". The Tizian "table tops" were then adhesively cemented on the natural teeth with Variolink II (Ivoclar Vivadent). A **SS-OCT** system has been used to evaluate the marginal and internal adaptation of Tizian "table tops". The **SS** (Axsun Technologies, Billerica, MA) has a central wavelength of 1060 nm, a sweeping range 106 nm (quoted at 10 dB), and a 100 kHz line rate. The depth resolution of the system, measured experimentally in air was 10 µm. The same samples were analyzed by using a micro-computed tomography (**µCT**) system, in order cu confirm the data obtained by using **OCT**. The imaging system used for this study offers good spatial resolutions in both directions, transversal and longitudinal, of around 10 µm, a high sensitivity, and it is also able to acquire entire **3D** volumes as fast as 2.5 s. Once the full dataset has been acquired, rendered high resolutions *en-face* projections could be produced. With it, the "table top" – cement – abutment tooth interfaces were observed on both C-scans as **2D** images and also in the **3D** reconstructions; the system was able to detect several open interfaces, which were confirmed on the **µCT** images. The **SS-OCT** system allows for an efficient evaluation of biomimetic Tizian "table tops".

Keywords: optical coherence tomography (OCT), swept source, biomedical imaging, dentistry, Tizian "table tops", pathologic wear, bruxism, dental interfaces.

1. INTRODUCTION

"Table tops"/occlusal veneers are partial crowns that allow for the biomimetic restoration of worn teeth [1, 2]. The biomimetic approach includes a computer-aided design and manufacturing (**CAD/CAM**) composite resin for the fabrication of the "table tops", for example Tizian, which is a zirconia reinforced composite (Schutz Dental Group) [3]. The prognosis of such restorations depends also on their marginal fit; large marginal gaps are associated with early dissolution of the cement layer and failure of the crown [4].

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Optical Coherence Tomography (OCT) is a non-invasive high resolution imaging method [5-7], that has been used by our group for the investigation of the marginal fit of different restorations; we analyzed the microleakage at prosthetic interfaces [8-10] and the quality of marginal adaptation and gap width of Empress veneers [11].

In the present study we prove the value of a fast swept source optical coherence tomography (**SS-OCT)** system in the evaluation of the marginal fit of Tizian "table tops".

2. MATERIAL AND METHODS

12 maxillary first premolars were extracted and minimally invasive prepared for "table tops", without conservation of the marginal ridges (occlusal veneers) (Fig. 1). This type of partial crowns restores the normal morphology of the entire occlusal surface. The teeth were further mounted in Frasaco models, while taking care to establish correct occlusal and proximal contacts.

The Tizian "table tops" were dry-milled in the Tizian Cut 5 smart CAD/CAM system and were adhesively cemented on the natural teeth with Variolink II (Ivoclar Vivadent) - Fig. 2.

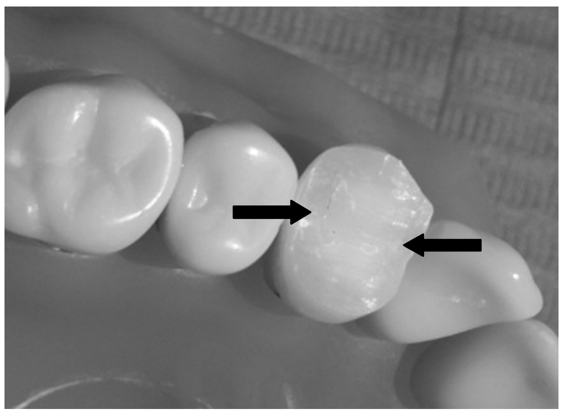


Figure 1. Right maxillary first premolar minimally invasive prepared for a Tizian "table top", without conservation of the natural marginal ridges (at black arrows).

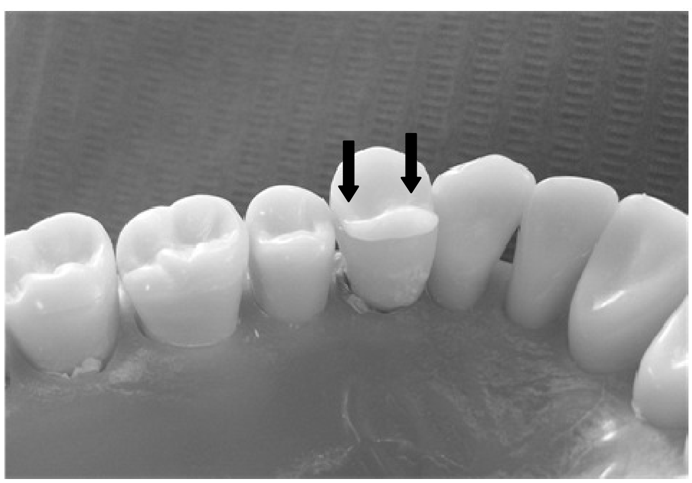


Figure 2. A Tizian "table top", with an occlusal thickness of 1 mm at the developmental grooves (at black arrows).

An in-house developed **SS-OCT** system was used to evaluate the marginal and internal adaptation of Tizian "table tops". The **SS** (Axsun Technologies, Billerica, MA) has a central wavelength of 1060 nm, a sweeping range 106 nm (quoted at 10 dB), and a 100 kHz line rate. The depth resolution of the system, measured experimentally in air was 10 µm. Figure 3 presents a schematic diagram of the SS OCT imaging system used for our study; details on this system can be found in [12]. The **OCT** images were further used to create **3D** reconstructions of the examined samples.

The same samples were analyzed by using a micro-computed tomography (**µCT**) system, in order cu confirm the data obtained by using **OCT**. We used the X-ray system phoenix microme|x DXR HD equipped with an unique temperature stabilized detector GE DXR250RT, a 180 kV/20 W microfocus X-ray tube and CT-Option. It combines the high resolution 2D X-ray technology and CT in one system. The results of the CT scanning were evaluated and saved with the Volume Graphics Max Studio Max 2.2 software. The CT data analysis obtained with this software can be viewed interactively by using the myVGL 2.2 application.

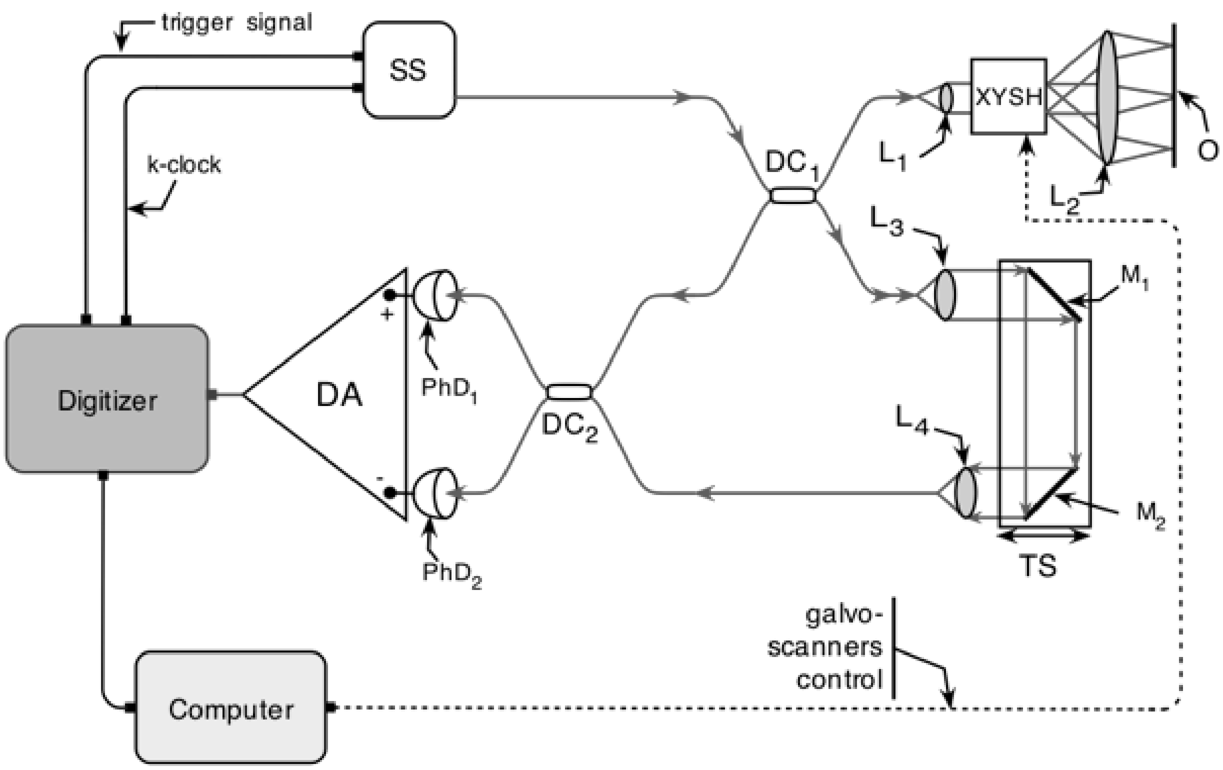


Figure 3. Schematic diagram of the SS-OCT system. Components: SS: swept source; DC_1: 20/80 single mode directional coupler; DC_2: 50/50 single mode directional coupler; XYSH: two-dimensional XY lateral scanning head [13]; L_1 to L_4: achromatic lenses; O: object to be imaged; PhD_1, PhD_2: photo-detectors; DA: differential amplifier; TS: translation stage.

3. RESULTS AND DISCUSSION

OCT allows for the imaging of prosthetic restorations because of its micrometer resolutions and millimeter penetration depths [5, 6]. The **SS OCT** technique has increased speed and better resolution as compared to the initially developed Time Domain OCT systems [7].

In this study we prove the advantages of a fast **SS OCT** system in the evaluation of Tizian "table tops". Tizian (Schütz Dental Group) is a zirconia reinforced composite, well suited for biomimetic restorations [3]; it has a "buffer action" and a low Young's modulus (similar to the dentine modulus). The imaging system used for this study offers good spatial resolutions in both directions, transversal and longitudinal, of around 10 µm, sensitivity as high as 94 dB, and it is also able to acquire entire 3D volumes of 500 x 500 pixels in the transversal section as fast as 2.5 s. Once the full dataset was acquired, rendered high resolutions *en-face* projections could be produced. The "table top" – cement – abutment tooth interfaces were observed on both C-scans as **2D** images, and also in the **3D** reconstructions; these images were then compared with the **µCT** data.

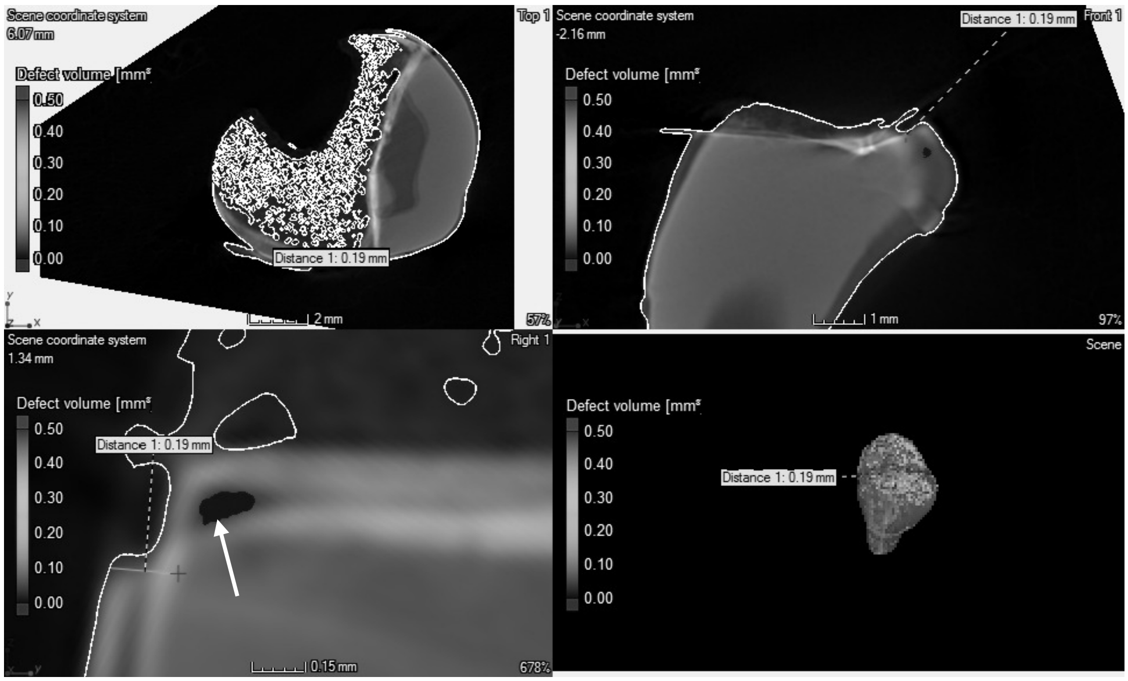
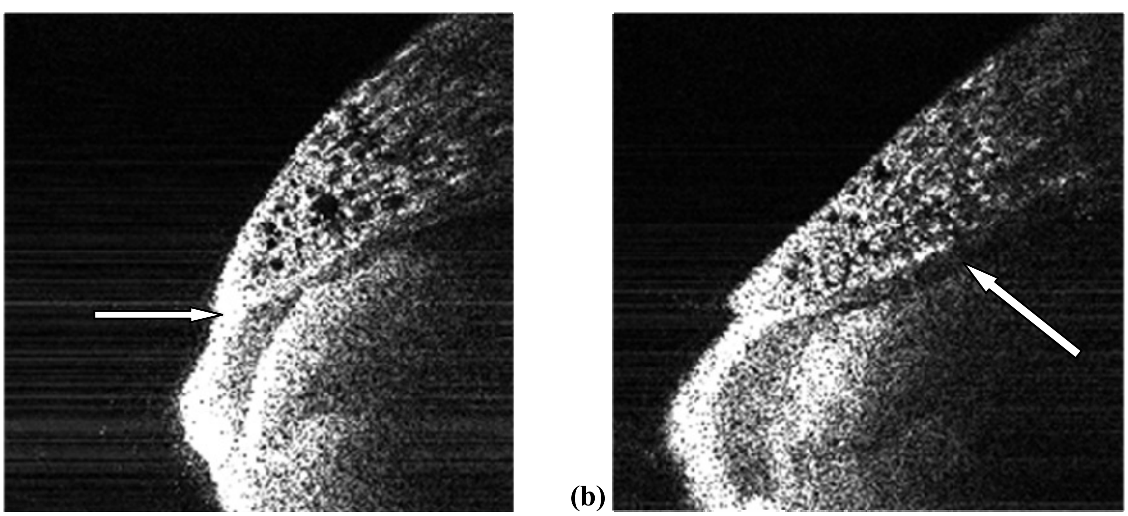


Figure 4. Large marginal gap on the distal surface of sample 7, combined with a consistent internal defect in the luting cement layer - at white arrow (**µCT** sections and 3D reconstruction).



(a) (b)

Figure 5. SS-OCT system images of the distal surface of a sample 7: (a) large marginal gap at white arrow and (b) internal defect in the luting cement layer at white arrow. Both images have a size of 2.8 x 2.8 mm.

The marginal fit was clinically acceptable on all axial surfaces of the samples, except for sample 7; on the **µCT** images we detected an excessive marginal gap on its distal surface (over 120 µm) and a large inner defect in the luting cement layer (Fig. 4). The marginal and internal defects were clearly detected by our fast **SS-OCT** system (Fig. 5).

4. CONCLUSIONS

The in-house developed **SS OCT** system has been efficient in the marginal evaluation of zirconia reinforced composite "table tops". It allows for the assessment of these biomimetic restorations – to see if they have a clinically acceptable marginal fit or not. The future development of the master-slave OCT technology [12], the application of galvoscanners in OCT [13], and the newly developed handheld scanning probes [14] create the basis for *in vivo* imaging of pathological dental wear and biomimetic restorations in bruxing patients.

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