Ceramic Veneers Integrity Investigation by Opical Coherence Tomography and MicroComputer Tomography

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Abstract: - The aim of this study was to analyze the integrity of the ceramic veneers using a noninvasive method like the optical coherence tomography working in Time Domain. The obtained results were validated by Micro Computer Tomography. The conclusions point out the importance of investigation the integrity of every veneer before bonding in into the oral cavity.

Key-Words: - Ceramic Veneers, Optical Coherence Tomography, Micro Computer Tomography

1. Introduction

Cosmetic dentists have been using porcelain veneers for smile makeovers for more than 30 years. While the prognosis of porcelain veneers was uncertain at the beginning, abundant dental literature can be found that reports about the clinical longevity of porcelain veneers.

Porcelain veneers have become the most used component at offices that focus on cosmetic dentistry. Many times patients wonder whether they want to take the risk of having their teeth prepared to receive beautiful porcelain veneers. While these concerns are understandable, tooth reduction is necessary to create anatomically correct teeth. For the same reason, so-called lumineers are rarely applicable. Lumineers are placed on unprepared teeth which causes them to be over contoured and too bulky. In addition, they do not permit the integration in the dental arch.

There are many different ways to prepare teeth for porcelain veneers. Each clinical situation requires a different design. The cosmetic dentist needs to be familiar with his craft to provide for his patient the most conservative and most appropriate preparation design before placing porcelain veneers. While is desire to prepare teeth minimally and remain in the enamel for superior bonding strength, it is sometimes necessary to prepare teeth into the dentin. This may be required when correcting severely misaligned teeth or when prior dental restoration are being replaced. However, a skilled cosmetic dentist knows how to provide an optimum preparation for any situation. In addition, an experienced cosmetic dentist understand the chemistry of his products and knows how to work with them to obtain optimum bonding results and superior longevity of porcelain veneers. The study of Kihn PW and colab reported that all veneers evaluated after 48 month were still clinically acceptable [1]. Many other studies demonstrated the same reliability of porcelain veneers. However, it become evident that the quality and longevity of porcelain veneers depends on the experience of the operator. Cosmetic dentists who are accredited by the American Academy of Cosmetic Dentistry have proven that have a high level of experience and understanding of all aspects of cosmetic dentistry. It is therefore logical to conclude that porcelain veneers placed by an accredited cosmetic dentist are more likely to be reliable and highly satisfactory for a long time.

The objective of Guess PC and colab. studies was midterm evaluation of a prospective five years clinical study on long term performance and success rate of pressed-ceramic veneers with two extended preparation design. Anterior teeth of 25 patients were restored with 66 extended veneers. Forty-two overlap veneers (incisal edge reduction 0,5 – 1,5 mm, butt-joint) and 24 full veneers were inserted. Both veneer design were similar in buccal (0,5 mm) and proximal (0,5 – 0,7 mm) chamfer preparation, but differed in palatal extension. Ceramic veneers

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were fabricated with IPS Empress and adhesively luted with dual polymerizing composite Variolink II (Ivoclar Vivadent). Clinical reevaluation was performed 6, 12, 25, 39, 45 and 62 months after insertion of the veneers according to the modified USPHS criteria. Absolute failures were recorded as survival rate, relative failures demonstrated by Kaplan-Meier success rate [2]. After an observation time up to 5 years, survival rate of full veneers was 100%, of overlap veneers 97,5% due to one severe fracture. Kaplan-Meier analysis of the relative failures in a success rate of 85% for full veneers and 72% for overlap veneers. Reasons for relative failures were cracks, ceramic-cohesive-fractures, and loss of adhesion. No significant differences were found between the two veneer groups. Secondary caries and endodontic complications did not occur. Increased clinical service time resulted in enhanced marginal discoloration and decrease of marginal adaptation. Extended pressed-ceramic veneers proved to be reliable procedures to restore larger deficits in anterior teeth. Pronounced palatal extension of full veneers was not linked to a higher failure probability. Reliable adhesive bonding, as well as ceramic fatigue and resistance are considered key factors for long term success of extended veneer restorations.

An up to 16 years prospective study of 304 feldspathic porcelain veneers prepared by the same operator in 100 patients was performed by Layton D and colab. [3]. A total of 304 porcelain veneers on incisors, canines and premolars in 100 patients completed by one prosthodontist between 1998 and 2003 were sequentially included. Preparations were designed with chamfer margins, incisal reduction and palatal overlap. At least 80% of each preparation was in enamel. Feldspathic porcelain veneers from refractory dies were etched (hydrofluoric acid), silanated and cemented (Vision 2, Mirage Dental Systems). Outcomes were expressed as percentages (success, survival, unknown, dead, repair, failure). The results were statistically analyzed using the chi-square test and Kaplan-Meier survival estimation. Statistical significance was set at $P < 0, 05$. The cumulative survival for veneers was 96% +/- 1% at 5 to 6 years, 93% +/- 2% at 10 to 11 years, 91% +/- 3% at 12 to 13 years and 73% +/- 16% at 15 to 16 years. The marked drop in survival between 13 and 16 years was the result of the death of 1 patient and the low number of veneers in that period. The cumulative survival was greater when different statistical methods were employed. Sixteen veneers were associated with esthetics (31%), mechanical complications (31%), periodontal support (12,5%), loss of retention >2 (12,5%), caries (6%) and tooth fracture (6%). Statistically significantly fewer veneers survived as the time in situ increased. Feldspathic porcelain veneers, when bonded to enamel substrate, offer a predictable long term restoration with a low failure rate. The statistical methods used to calculate the cumulative survival can markedly affect the apparent outcome and thus should be clearly defined in outcome studies.

Marginal adaptation of the ceramic veneers was investigated by Sinescu C and colab [4], [5]. 32 Empress Veneers (Ivoclar Vivadent, Lichtenstein) were investigated using en face Optical Coherence Tomography (OCT). The scanning procedure was performed vestibular, oral, mesial and distal for each sample. All the samples were bonded with the same adhesive cement. Two en-face OCT systems have been used. Both use similar pigtailed superluminescent diodes (SLD) emitting at 1300 nm and having spectral bandwidths of 65 nm which determine an OCT longitudinal resolution of around 17.3 μm in tissue. The first OCT system is a combined OCT/confocal system, which is equipped in addition with a confocal channel at 970 nm and uses a high NA interface optics allowing 1 mm image size. The en face OCT scanning reveals pour marginal adaptation for some ceramic veneers (18 samples). The marginal adaptation problems were identified especially in proximal and oral areas. The lack of the adhesive cement could lead to cavities in the depicted areas. Also the gaps from the veneers and the teeth could initiate debonding. A normal eye inspection or an inspection with the dental instruments could not detect those problems because of the small dimensions of the defects. In times, because of these cavities, a sensitivity of the pulp could occur due to incorrect marginal adaptation of the veneers. For all those reasons a non invasive method like en face Optical Coherence Tomography is necessary to investigate and evaluate the prognostic of the bonded ceramic veneers.

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2. Problem Formulation

The aims of this study were to evaluate the integrity of the dental ceramic veneers before setting them in the oral cavity in order to depict the defects inside the ceramic layers and to prevent the prosthetic fracture and failure.

3. Problem Solution

54 Empress Veneers (Ivoclar Vivadent, Lichtenstein) were investigated using en face Optical Coherence Tomography (OCT) (Fig.1.). The scanning procedure was performed vestibular, oral, mesial and distal for each sample (Fig.2.). Two *en-face* OCT systems have been used. Both use similar pigtailed superluminescent diodes (SLD) emitting at 1300 nm and having spectral bandwidths of 65 nm which determine an OCT longitudinal resolution of around 17.3 μm in tissue. The first OCT system is a combined OCT/confocal system, which is equipped in addition with a confocal channel at 970 nm and uses a high NA interface optics allowing 1 mm image size. The configuration of the second system, as shown in Fig. 1, uses two single mode directional couplers. Light from the SLD source is injected into the system via the directional coupler DC1 which splits the light towards the two arms of the interferometer, the probing and the reference arm respectively. The probing beam is reflected by the dichroic beam splitter BS1 and then sent via the galvanometer scanners SX and SY to the sample. Two telescopes incorporated between these elements conveniently alter the diameter of the beam in order to match the aperture of different elements in the probing path and convey a probing beam of around 8 mm in diameter through the microscope objective MO's pupil plane. Hence, a lateral resolution of around 2 μm in the confocal channel could be achieved.

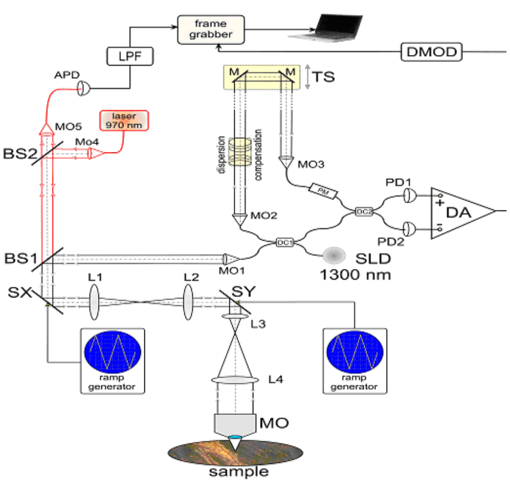

Fig.1. *En-face* OCT at 1300 nm/confocal at 970 nm system. SLD = superluminescent diode, SX, SY: X and Y scanners; IMG = index matching gel; APD: avalanche photodiode; L1, L2, L3, L4: lenses: MO1-5: microscope objectives; PD1, 2: pin photo detectors; BS1,2: beam splitters; LPF: low pass filter; PM: polarization

A transversal resolution better than 5 microns is obtained in the OCT channel. Light back-scattered by the sample passes a second time through the object arm and is guided towards the single mode directional coupler DC2 via DC1 where it interferes with that coming from the reference arm. Both output fibers from DC2 are connected to two pin photo-detectors in a balanced photo-detection unit. A computer driven translation stage (TS) is used to construct B-scan images by stopping the frame scanner and moving TS along the optical axis of the reference beam.

Fig. 2. Aspects from the scanning procedure of the ceramic veneers.

For the MicroCT, the samples were scanned using cone beam micro-CT [6] (Fig. 3). The cone-beam micro-CT scanner consists of a micro-focal spot x-ray tube (10-20 μm), xyz+rotary stage, and a micro-angiographic detector with a 45 microns pixel size. The x-ray exposure parameters were: 40 kVp, 1 mA and 300 ms exposure per frame. The samples were placed onto the rotary stage at a magnification between 2 and 1.1 depending on the sample size and scanned using one degree step increments. After projection acquisition they were reconstructed using a $(512)^3$ volume with a 45 $microns^3$ per voxel.

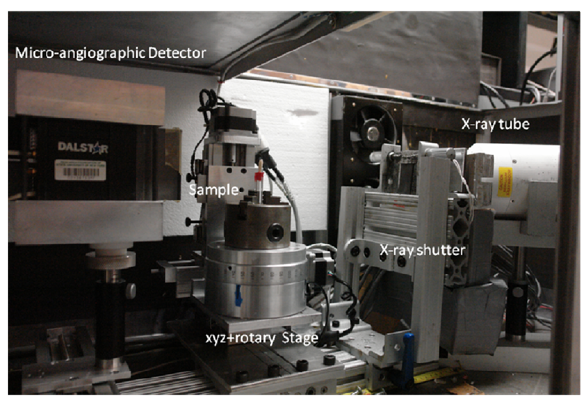

Fig. 3. Aspects of the Cone Beam Micro-CT setup.

4. Results

The results obtained after the OCT investigation in Time Domain pointed out some defects inside the ceramic layers of the veneers (Fig. 4 to 9). In order to observe better the defects a 3D reconstruction was performed (Fig. 10, 11).

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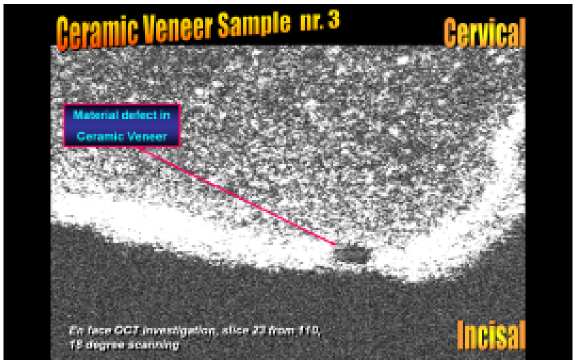

Fig. 4. Material defect inside the ceramic veneers in the incisal area.

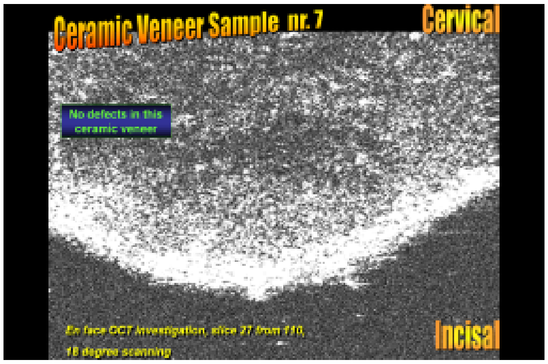

Fig.5. Ceramic sample with no defect inside the ceramic layers.

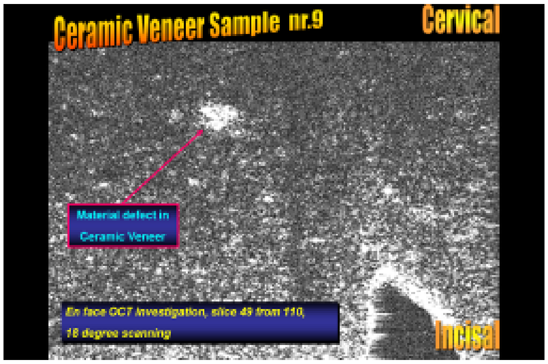

Fig. 6. Defect depicted inside the ceramic veneer sample nr. 9. Slice 49 from 110, 18 degree scanning.

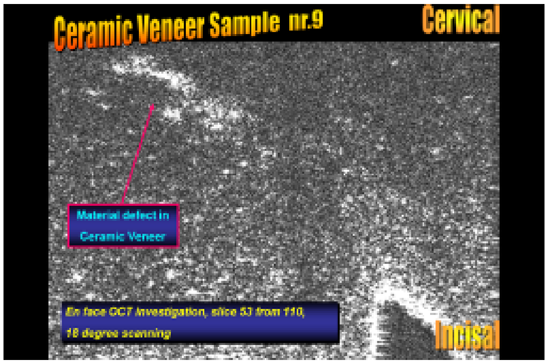

Fig. 7. Defect depicted inside the ceramic veneer sample nr. 9. Slice 53 from 110, 18 degree scanning.

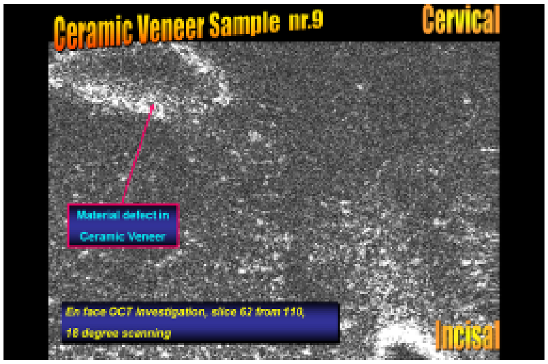

Fig. 8. Defect depicted inside the ceramic veneer sample nr. 9. Slice 62 from 110, 18 degree scanning.

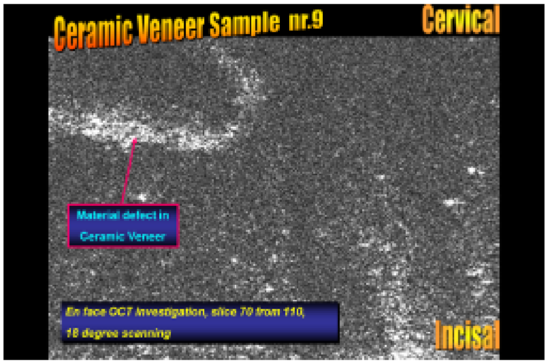

Fig.9. Defect depicted inside the ceramic veneer sample nr. 9. Slice 70 from 110, 18 degree scanning.

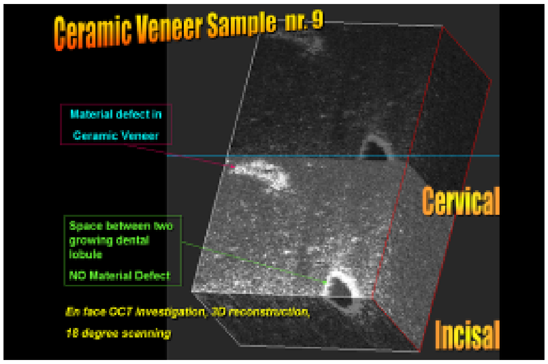

Fig. 10. 3D reconstruction of ceramic veneer sample nr 9 showing a defect inside the ceramic layers.

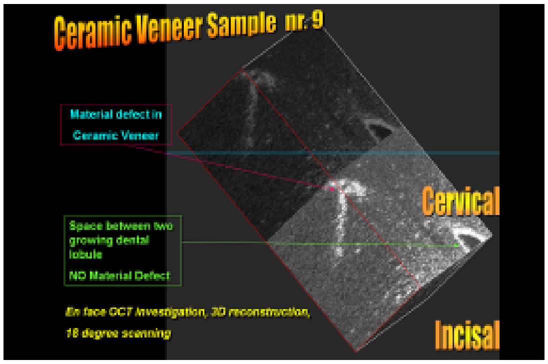

Fig. 10. 3D reconstruction of ceramic veneer sample nr 9 showing a defect inside the ceramic layers.

All the defects depicted by OCT Time Domain investigations were validate by MicroCT analysis.

4. Conclusion

OCT could act as a valuable noninvasive method in analyzing the integrity of prostheses. This will save time and resources by eliminating prostheses with defects before they are mounted in the patient's oral cavity. The results obtained with the OCT working in Time Domain were validate by MicroCT investigations.

Acknowledgments

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