An Imagistic Approach on Resin Composite Class I Dental Fillings with Improved Adhesive with Ferric Nanoparticles

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Dental composite resins already have a history and a vast use in dentistry. In vivo and in vitro research gave precise directions and indications but the tests are not completely relevant. Different clinical parameters cannot be reproduced by in vivo and in vitro research. The evolution of dental materials leads to the use of nano materials. For the present study, were used human extracted teeth on which were prepared class I cavities. For half of the samples had been used normal adhesive and composite resin and for the second group was used nanomaterials- a ferric nanoparticles modified dental adhesive was used and then filled with the same resin composite material. The interfaces generated by hard dental tissue and classical adhesive and adhesive made from nano-particles were investigated through micro-CT imagistic investigation method. With the software VGStudio MAX the 3D reconstruction of the constituents were made. Micro-CT using the synchrotron technology and 3D reconstruction offers important details and of high quality of investigated area. All the samples were imagistic investigated through, X-ray, SEM and EDAX technologies. Each investigation method spotted the defects of the investigated area according to its limitation.

Keywords: composite resin, dental adhesive, feeric nanoparticles, micro-CT, X-ray, SEM, EDAX

Composite resins designed for restoration of posterior teeth are used since 1980s. Once with their debut in dentistry, these materials become very popular for their advantages. Along with the enthusiasm, were made speculations about the material clinical performances and behaviour. Dental composite resin was the most investigated research subject materialized in publications.

The use of composite resins for anterior teeth restoration was a success but the use in the restoration of posterior teeth have been questioned. Polymerization shrinkage and tendency to wear are the main issues. Composite resins had benefit by complex in-vitro tests designed to evaluate the durability of direct composite resins in the oral cavity. The simulations of clinical conditions were strictly reproduced but even so, the in vivo conditions vary. Parameters like functional stress, mastication, surface tension and flow of fluids through dentin tubes are variables that cannot be part of in vitro-tests. Accurate clinical evaluation of resin composites cannot be based only on laboratory tests. Long-term studies of clinical performance should be the goal in research of composite resins.

Investigation systems like Micro-computed tomography or micro-CT are employed in the research domain of osteoporosis and bone research and investigation. Researchers in bone biology are constantly using micro-CT [1, 2].

This article is focused on extensive background of physics for comprehending the methodology and its limitations and on the micro-CT bone analysis and technique.

Density measurements and morphometrics along with a brief examination of the micro-CT method are the main subjects of this article. Applications of micro-CT, ex vivo and in vivo analysis of bone structure will be presented in a concise and structured review. "Computed tomography" technique consists of X-ray projection images of an object. The projections are taken from many angles around the object. These images are mathematically processed and the convert into cross-section image slices. The final result is materialized into a 3D image [3]. The three dimensional reconstruction is obtained after a total rotation of 180 or 360 degrees of the source around the scanned object. Each projection X-ray image is a 2D image. The rotation of the X-ray imaged sample and source camera allows the precise calculation of the 3D image because the all angle rotation [4].

CT technology has been an important and useful technology in medical domain [5]. It is part of diagnostic protocol since 1972 when Godfrey Hounsfiled invented the technique. Micro-CT is actually the CT of small objects or samples investigated with dedicated scanners with very high spatial resolution. Figure 2 represents a micro-CT in vivo scan of a mouse hind limb [6].

Experimental part

42 human extracted teeth (human premolars) crack-free were randomly selected for this study. The teeth were stored in physiological saline solution prior to use. A standardized class I cavity was prepared on the surface of each tooth using a regular grit fissure diamond bur (no. 835, ISO 806 314 108 524 018, Hager&Meisinger, Neuss, Germany). 21 samples were grouped for fillings with normal dental adhesive and composite resin material. In the other 21 samples a ferric nanoparticles modified dental adhesive was used and then filled with the same resin composite material. The cavities were conditioned as follows: total acid etching, 15 s with 37.5% phosphoric

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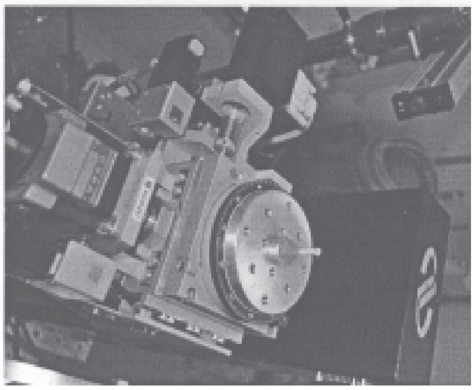

Fig. 1. Micro-CT investigations using the Synchrotron Radiation at the SYRMEP Beamline of the ELETTRA Synchrotron Radiation Facility (Trieste, Italy)

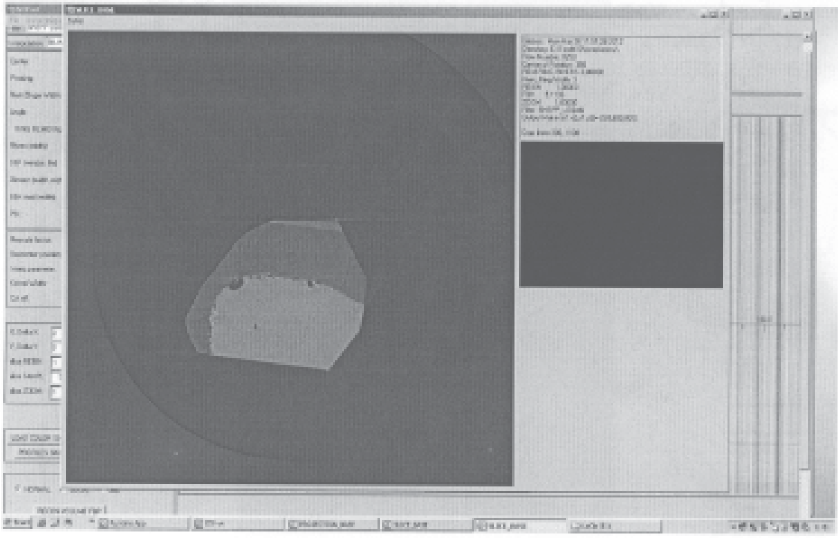

Fig. 2. The sample nr 10 with the modified adhesive after the synchrotron evaluation

acid Gel Etchant (Ivoclar Vivadent), then aplication of Syntac (Ivoclar Vivadent) adhesive. All cavities were bulk filled with IPS Empress Direct (Ivoclar Vivadent) composite. IPS Empress Direct is a universal nano-hybrid filling material for direct esthetic restorative procedures. IPS Empress Direct provides a high gloss polish and the lifelike opacity, fluorescence and opalescence that is required to fabricate beautiful and naturally esthetic restorations with remarkable efficiency.

The interfaces were examined by the microCT using the synchrotron technology (fig. 1). A synchrotron radiation X-Ray micro-CT experiment was performed at the SYRMEP Beamline of the ELETTRA Synchrotron Radiation Facility (Trieste, Italy) – fig. 1. The 1200 radiographic projections were acquired with beam energy of 29 keV over 180° with a pixel size of 9 μm. A sample – detector distance of 15 cm was considered in order to have both absorption and phase-contrast signal, for a better viewing of the interfaces.

The tomographic reconstruction was performed by means of the common filtered back-projection method. For 3D visualization, data volumes were rendered directly without decomposing them into geometric primitives. A commercial software - VGStudio MAX - was used to generate 3D images and to visualize the distribution in 3D of different constituents.

All the samples were investigated with X ray and then the samples were evaluated with SEM and EDAX. A scanning electron microscope (SEM) is a type of electron microscope that images a sample by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition, and other properties such as electrical conductivity.

EDX Analysis stands for Energy Dispersive X-ray analysis. It is sometimes referred to also as EDS or EDAX analysis. It is a technique used for identifying the elemental composition of the specimen.

The EDX analysis system works as an integrated feature of a scanning electron microscope (SEM), and can not operate on its own without the latter. The output of an EDX analysis is an EDX spectrum. The EDX spectrum is just a plot of how frequently an X-ray is received for each energy level. An EDX spectrum normally displays peaks corresponding to the energy levels for which the most X-rays had been received. Each of these peaks is unique to an atom, and therefore corresponds to a single element. The higher a peak in a spectrum, the more concentrated is the element in the specimen. An EDX spectrum plot does not only identify the element corresponding to each of its peaks, but the type of X-ray to which it corresponds as well.

Results and discussions

VGStudio Max software gives a comprehensive 3D visualization of the reconstructed specimen, allowing the segmentation of the grey histogram, in order to visualize only the phases of interest in the imaged volume [7]. It allows a direct view of three orthogonal axis (Axial, Sagittal and Frontal), together with the 3D image that can be rotated or slices in any direction for a good visualization of the morphology of the reconstructed specimen.

On the microCT slices the interface between the dental structure and the modified dental adhesive along with the dental filling can be observed (fig. 2). The porosity of the composite material can be evaluated slice by slice or in the entire sample (fig. 3).

The microscopic evaluation of the samples with modified adhesive reveals improved scattering interfaces between the dental structure and the composite resin (fig. 4). This will enhance the quality of the imagistic investigations in order to have a proper delimitation. However, no porosity is detected on this kind of investigation [7-9].

On the Rx investigations is difficult to observe the differences between the samples with normal adhesive (fig. 5, b) and those with ferric nanoparticles modified adhesive (fig. 5, a). Only the presence of a big material defect between the dental structure and the dental filling is detected (fig. 5,a).

On the SEM investigations the adhesive layer appears in good contrast with dental structure and dental filling (fig. 6). The width of the modified adhesive layer could be quantified (fig. 6). The proof of the existing modified adhesive inside the considered layer was done by EDAX after the definition of the interested area (fig. 7). No porosity was detected on this kind of investigation.

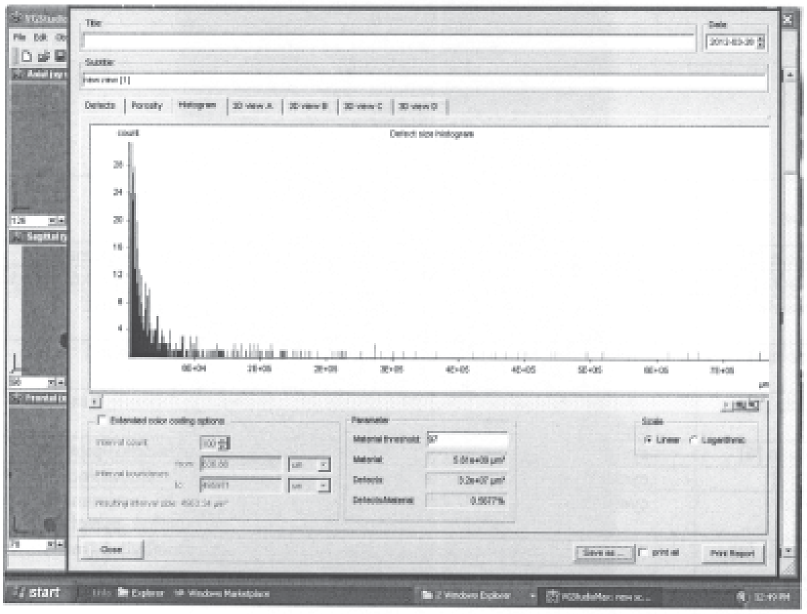

Fig. 3. The histograms of the porosity in the whole sample nr. 10

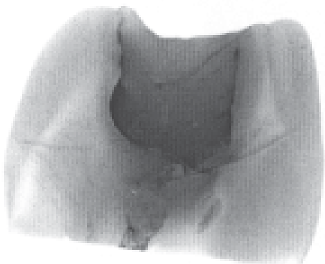

Fig. 4. Microscopic aspect of the fillings with the modified adhesive.

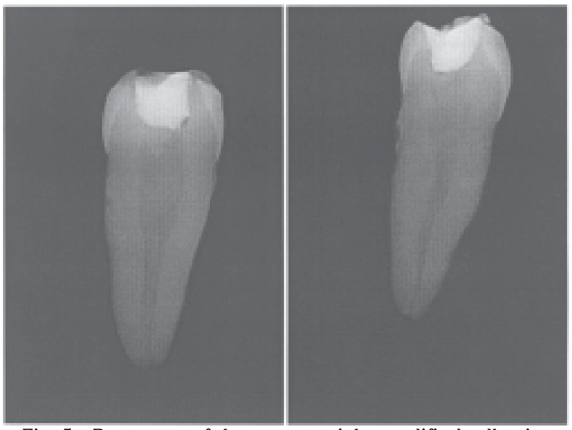

Fig. 5. Rx aspect of the nanoparticle modified adhesive sample (a) compared with the one with normal dental adhesive (b)

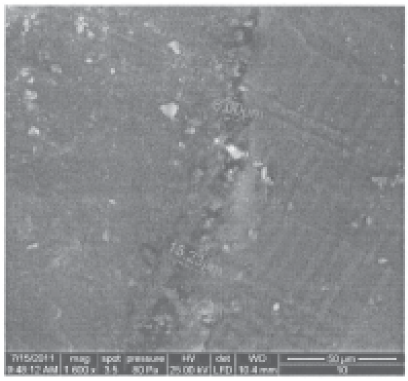

Fig. 6. The SEM evaluation of a sample with modified adhesive using ferric nanoparticles. The dimensions pointed out represent the width of the modified adhesive layer

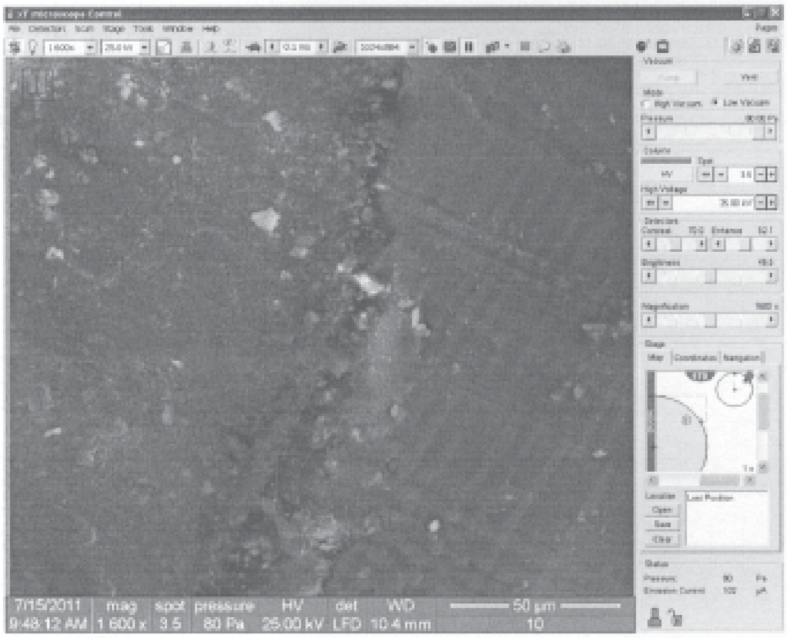

Fig. 7. The EDAX evaluation of the modified adhesive layer.

Conclusions

In conclusion, noninvasive evaluations methods such as the microCT evaluation using the synchrotron radiation, have a great capability to evaluate the interfaces between dental structure, resin fillings and dental adhesive when a ferric nanoparticles modified adhesive is used. With respect to to the limitations of this study, further research is needed in order to observe the implications of this type of adhesive in the adhesion on dental structure.

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