Researches Regarding the Improvment of Different Dental Contemporary Composite Materials Structure

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The purpose of this study was to test the structural improving that may be acquired by adding hydroxyapatite microparticles bearing or not silver nanoparticles to three different commercial products commonly used in dental practice. The practical part of this study consisted in the preparation of a common protocol of nine samples resulting from the creation of cavities and their filling similarly to the solving of different clinical situations of carious processes, extracted teeth belonging to both the anterior and the posterior area, with different architectures of the loss of dental substance. Before use, both HA and HA/AgNP have been subjected to calcination in an oven at 600⁰C for three hours in order to eliminate the residual organic matter. The structural changes have been studied on three types of composites known in the medical practice under the tradenames of Ceram X Duo, Swiss Tec and Herculite XRV Ultra. The structural changes materialized at the level of dentinal component are clearly visible in the SEM images recorded for each starting commercial material. Thus, the addition of HA with high polydispersity (within the range of tens of nanometers and several microns) was effective on lowering the surface rugosity and apparent macro-porosity, while enhancing the phase mixing and component cohesion, but only in the case of Ceram X Duo and Swiss Tec materials. For Herculite XRV Ultra these effects seems to be limited or even reversed, phenomenon that could be explained by the fact that this material already contains nano-fillers, and their concentration tends to saturation.

Keywords: odontal reconstruction, composites, hydroxyapatite, silver nanoparticles, SEM

In the context of evolution that governs contemporary dentistry, the dental biomaterials from odontal reconstruction domain record an upward dynamic, aiming to obtain an aesthetically and biomechanically optimal [1-4]. The success of an odontal restoration consists in the full agreement of a relative wide number of particularly important working parameters, like the specific location of loss in odontous substance, the physiological and biomechanical particularities of each clinical situation, which should be always corroborated with the structure of the chosen restorative biomaterial [5,6]. The use of adhesive techniques based on biomimetic composites in various clinical situations requiring dental restorations has been imposed in the last decade as a current non-invasive approach to dental practice, since it conducts to superior properties in terms of mechanical resistance, adherence, aesthetic demand, texture and surface characteristics superposed on the dental structure [7-10]. In fact, the aesthetic-biocompatibility-biomechanical trinoma stands at the basis of all designs envisaged to improve the performance of dental composites, in full compliance with the elaboration of a complex analysis and control algorithm for each structural component, dentine and enamel, and in concordance with the evaluation of effects on adjacent biological tissues and interactions with the oral environment [11-15].

Thus, the success or failure of clinical work in remodeling restoration primarily depends on the intrinsic structure of composite materials, which in turn governs the biomechanical behavior, biological interactions at interface and optimal aesthetic rehabilitation. From this point of view, the supplementary filling of some commercial resins and composites with small amounts of bioactive compounds may enhance and extend their applicability in dental restoration. Therefore, the purpose of this study was to test the structural improving that may be acquired by adding hydroxyapatite microparticles bearing or not silver nanoparticles to three different commercial products commonly used in dental practice.

Experimental part

Materials

The hydroxyapatite powder (HA), silver nitrate, orthophosphoric acid, and sodium hydroxide were obtained from Sigma-Aldrich as reagent grade materials, while the sodium lignosulphonate powder was purchased from Carl Roth. The hydroxyapatite bearing silver nanoparticles (HA/AgNP) was prepared as previously reported [7]. Before use, both HA and HA/AgNP have been subjected to calcination in an oven at 600⁰C for three hours in order to eliminate the residual organic matter. The structural changes have been studied on three types of composites known in the medical practice under the tradenames of Ceram X Duo, Swiss Tec and Herculite XRV Ultra.

Methods

A common working protocol was employed for all samples, starting with the preparation of both front and side cavities from the extracted teeth according to the localization of tooth decay. In the next stage the cavities were prepared for filling by one minute demineralization with orthophosphoric acid. After acid removal, the cavities were washed and dried, adhesive applied and photo-polymerized for 20 s, and in the next stage the unmodified acrylate-based commercial composite material was photo-polymerized for 20 s, and subsequently applied to cavities in layers of 2 mm. This procedure was furthermore repeated with the commercial materials modified by

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addition of either HA or HA/AgNP powder, which results in a total of nine distinct samples. The three types of composite materials were polymerized using the Woodpecker LED C light-curing lamp which uses the principle of bright light for a much faster resin solidification and much lower radiation.The main characteristics of the light-curing lamps used were represented by power: AC 100V-240V 50 / 60Hz; wavelength: 420 - 480 nm and luminous intensity: 1000mW / cm² -1200mW / cm². The morphology of all samples was analyzed through a Quanta200 (FEI) low vacuum scanning electron microscope (SEM).

Results and discussions

The creation of cavities and their filling has been similarly treated like the usual solving of different clinical situations of carious processes related to extracted teeth belonging to the both anterior and posterior area, and with different architectures as concerning the loss of dental substance (fig.1).

Fig.1 The aspect of all samples

It is known that the Universal Ceram.X SphereTEC One Composite is based on advanced SphereTEC technology of a granular filler material. SphereTECTM represents the micron scale production process of well-defined spherical superstructures containing submicron-sized glass particles (fig.2).

Fig. 2 Aspect of Ceram X composite used

SphereTEC particle morphology, particle size distribution and surface microstructure provide this material with good biomechanical and aesthetic parameters in conjunction with easy manipulation.

The new filling technology of spherical granules in combination with an optimized resin matrix system results in very good handling properties: easy adaptation to cavity walls, does not adhere to working tools, slightly demodulated, preserves its shape.

The new CLOUD shade concept is designed to achieve the superlativity of colors with those of the entire VITA key color range with a minimal number of universal shades. In this context, our structural changes have only concerned the dentin, not to change the desired final color by transparency. These aspects correlate with the depth of the cavity and, in particular, the thickness of the layers applied.

Herculite XRV Ultra-represents an innovative nanohybrid composite that offers mechanical and aesthetic resistance very good parameters (fig.3).

Fig.3 Aspect of Herculite XRV Ultra used

Based on the latest nano-filling technology, besides improved handling and polishing properties and abrasion resistance, XRV Ultra gives a natural look to the final restorations, reflecting the opalescence and fluorescence of the natural tooth.

Is recommended for restorations front and back of class I to IV for the restoration of cervical erosions.

Swiss Composite is a photopolymerizable composite for anterior and posterior restorations for direct technique.

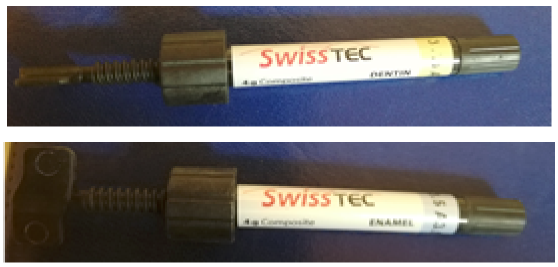

Fig.4 Aspect of Swiss composite used

It is characterized by a very good handling, easy to finish and polished (fig.4).

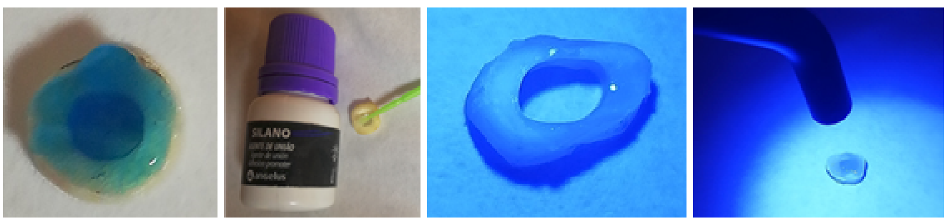

Fig.5 Protocol for making sample number 1 composed of ceramX, dentin and ceram X enamel

PROBE 2- Ceram X Duo applied in layers (from the base to the top: Ceram X Duo 1-dental layer enhanced with HA + the 2-layer Ceram X Duo enamel) (fig.6)

Fig.6. Sample Protocols made of composite ceram X, with the introduction of HA particles and silver particles at dentin level

PROBE 3 Ceram X Duo applied in layers (from the base to the top: Ceram X Duo 1-dental layer enhanced with HA and Ag + the 2-layer Ceram X Duo enamel) (fig.6).

PROBE 4 - Swiss Tec applied in layers (from top to bottom: Swiss Tec 1-dentine + Swiss Tec 2-enamel layer)

PROBE 5- Swiss Tec applied in layers (from the base to the top: Swiss Tec 1-dentine layer enhanced with HA + the 2-enameled Swiss Tec layer) (fig.7).

Fig.7 Sample Protocols made of Swiss Tec composite and Herculite XRV, with the introduction of HA particles and silver particles at dentin level

PROBE 6- Swiss Tec applied in layers (top to bottom: Swiss Tec 1-dental layer enhanced with HA and Ag + 2-enameled Swiss Tec layer) (fig.7).

PROBE 7- Herculite XRV Ultra applied in layers (from bottom to top: Herculite XRV Ultra layer 1 + dental layer Herculite XRV Ultra).

PROBE 8- Herculite XRV Ultra applied in layers (from bottom to top: Herculite XRV Ultra 1-dental layer enhanced with HA + 2-enamel layer (Herculite XRV Ultra Simple).

PROBE 9 - Herculite XRV Ultra applied in layers (from the bottom to the top: Herculite XRV Ultra 1-dental layer enhanced with HA and HA/AgNP + 2 layer enamel Herculite XRV Ultra simple) (fig.7).

The selection of hydroxyapatite and silver nanoparticles as supplementary additives for dental contemporary composite materials was justified by several reasons like their acceptance and frequent use in medical applications [8,9,12,16,17], excellent HA biomimetic, bioactive and osteo-integrative properties [16-18], and relevant therapeutic behavior exhibited by AgNP [13, 18-20].

A typical presentation of synthesized HA/AgNP, obtained on a transmission electron microscope (TEM) HT7700 (Hitachi) after calcination, confirms the presence of 10-20 nm AgNP randomly and infrequently dispersed on the surface of significantly higher sized HA plates (fig. 8). It must be noted that both HA and HA/AgNP were incorporated into the material composition at the level of dentinal component, while the enamel component was left unmodified.

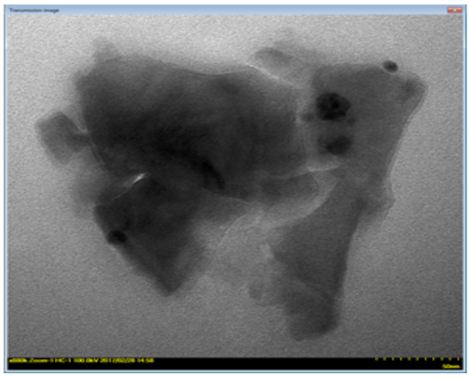

Fig. 8 Typical TEM image of HA/AgNP fillers

The structural changes materialized at the level of dentinal component are clearly visible in the SEM images recorded for each starting commercial material (figs.9-11).

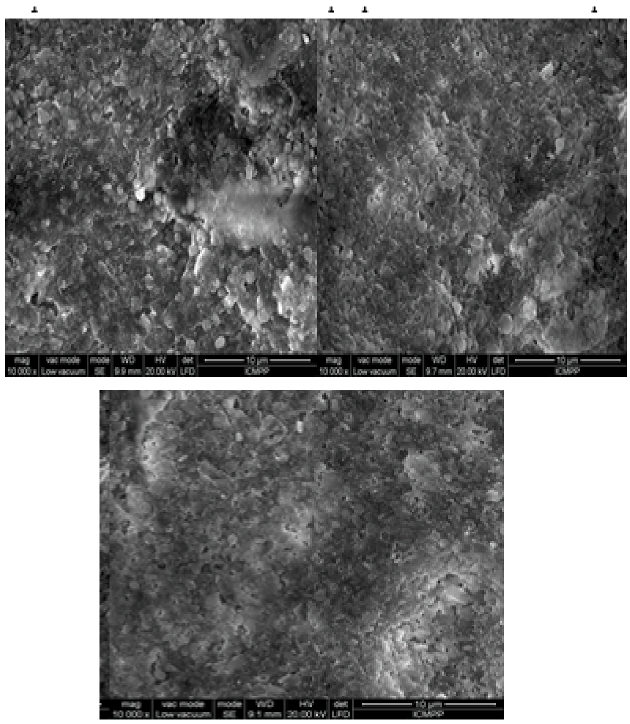

Fig. 9 SEM images of Ceram X Duo: unmodified (left), and respectively modified with HA (middle) or HA/AgNP (right) (10µm bar)

Thus, the addition of HA with high polydispersity (within the range of tens of nanometers and several microns) was effective on lowering the surface rugosity and apparent macro-porosity, while enhancing the phase mixing and

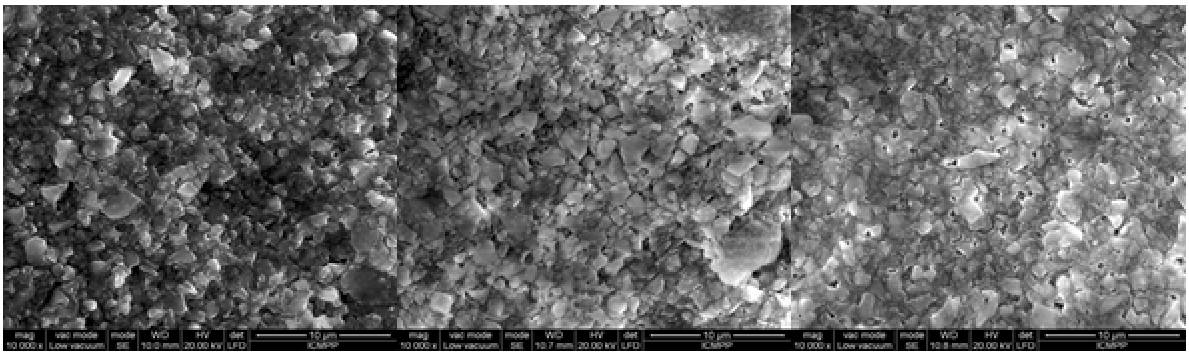

Fig.10 SEM images of Swiss Tec: unmodified (left), and respectively modified with HA (middle) or HA/AgNP (right) (10µm bar)

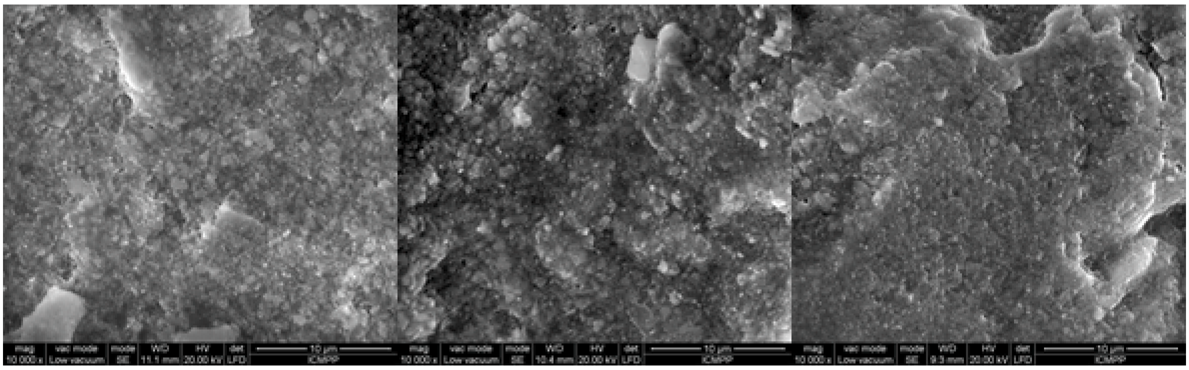

Fig.11 SEM images of Herculite XRV Ultra: unmodified (left), and respectively modified with HA (middle) or HA/AgNP (right) (10µm bar)

component cohesion, but only in the case of Ceram X Duo and Swiss Tec materials. For Herculite XRV these effects seems to be limited or even reversed, phenomenon that could be explained by the fact that this material already contains nano-fillers, and their concentration tends to saturation. As result, a small amount of supplementary filler material may enhance the phase separation, especially if the main particle sizes are generally higher. Surprisingly enough, the presence of AgNP on the surface of HA fillers further increases the phase compatibility and cohesion, limits the surface rugosity and appears to be also efficient for Herculite XRV. So, besides their antimicrobial and therapeutic properties, the AgNP supported on HA have an important contribution to the improvement of viscoelastic properties of composite materials. These results confirm that not only colloidal silver nanoparticles [20], but also the HA-supported ones have relevant implications on the viscoelastic properties of the host composite material.

Conclusions

In dental practice, the success or failure of clinical activity in remodeling restoration primarily depends on the intrinsic structure of composite materials, which in turn governs the biomechanical behavior, biological interactions at interface and optimal aesthetic rehabilitation.

The selection of hydroxyapatite and silver nanoparticles as supplementary additives for improving dental contemporary composite materials was justified by several reasons like their acceptance and frequent use in medical applications.

According with their antimicrobial and therapeutic properties, the AgNP supported on HA have an important contribution to the improvement of viscoelastic properties of composite materials.

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