Influence of Silver Nanoparticles on Mechanical Properties of Dental Acrylic Resins

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The purpose of our research is to evaluate the effects of silver nanoparticles (AgNPs), incorporated for antimicrobial reasons in dental acrylic resins, on their mechanical properties. A total of 30 rectangular cross-section of heat curing and 30 rectangular of self-curing acrylic resin specimens were made, and divided into three groups for both resins (ten for each), according to the concentration of AgNPs solution (5%, 10%, and 20% vol.) incorporated into the monomer. One control group without AgNPs for each resin was prepared, as well. The dimensions of the AgNPs, were 20 nm. The specimens were tensile tested to determine the Young's modulus, yield stress and tensile strength. The results indicate a reduction of the Young's modulus, yield stress and tensile strength for both resins after AgNPs incorporation, the lowest values being recorded in 20% concentration specimens. Within the limitations of this study, the mechanical properties of acrylic resins were influenced by AgNPs concentration, but without jeopardizing their clinical use. Since this research was limited to one size of AgNps, even for different concentrations, further studies are necessary to evaluate the effects of AgNps size on mechanical properties.

Keywords: acrylic resins, silver nanoparticles, mechanical properties, Young's modulus, yields stress, tensile strength.

Acrylic resins remain the preferred materials for removable compete and partial prosthesis, because of their favorable characteristics, such as adequate strength, good thermal conductivity, low weigh, acceptable aesthetics, low cost, easy to repair and relining [1,2].

One of the major disadvantages of removable prostheses is their insufficient mechanical strength, in certain clinical situations. In order to optimize the parameters several techniques of reinforcement of polymethyl methacrylate (PMMA) with other materials, such as carbon fibers, glass fibers, metallic inserts have been proposed [3, 4].

Another disadvantage that specialists faced is the mucosal irritation caused by microbial adhesion to inner denture surface. Epidemiological studies report that approximately 70% of removable denture wearers suffer from denture stomatitis, *Candida albicans* being regarded as essential prerequisites for denture stomatitis [5-7]. The elderly patients with removable acrylic prosthesis present difficulties on keeping the denture clean. To provide antibacterial properties, in the last years more attention has directed toward the incorporation of AgNps into polymers used as tissue conditioners and as denture base [8-11].

The purpose of our study is to evaluate the effects of AgNPs incorporated for antimicrobial reasons in dental acrylic resins, on their mechanical properties.

Experimental part

Materials and methods

For this study two types of acrylic resins commonly found in dental practice were used: one heat curing resin (Futura Basic Heat/Schutz Dental/Germany) indicated for complete and partial removable dentures, and one self-curing resin (Futura Basic Cold/Schutz Dental/Germany), used for relining and rebasing removable dentures, and for making the acrylic component of cast removable partial dentures.

The used AgNPs were 20 nm size, 0.02 mg/mL, in aqueousbuffer, containing sodium citrate as stabilizer (Lot #MKBV9651V/Sigma Aldrich/USA).

A total of 80 rectangular cross-section specimens, 40 for each type of resin were made and divided into four groups, depending on the concentration of AgNps, as follows:

Group 1: Control group-heat curing resin (HCR) without nanoparticles
Group 2: HCR with 5% AgNps
Group 3: HCR with 10% AgNps
Group 4: HCR with 20% Ag Nps

Group 1': Control group- self-curing resin (SCR) without nanoparticles
Group 2': SCR with 5% AgNps
Group 3': SCR with 10% AgNps
Group 4': SCR with 20% AgNps

Specimens preparation

The wax patterns were made of pink wax, 2 mm thickness, having the following dimensions: 75 mm length, 12.5 mm width (the extremities) and 4 mm in thickness (the central area) (fig.1).

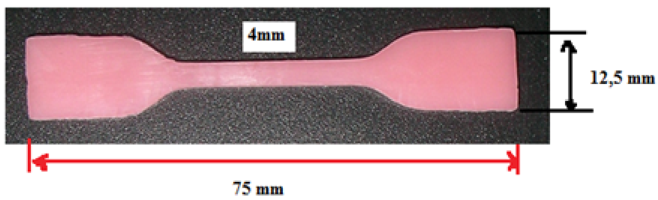

Fig.1 The specimen wax up

The wax patterns were transformed in acrylic specimens according to the same technology used for acrylic dentures. They were first invested in dental stone (Elite Rock class IV/Zhermack) in order to obtain a mold (fig..2a, b). After the mold isolation with a separating agent (Isodent/Spofa Dental), the acrylic resin pastes were

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prepared, following the producers indications for each type. For Futura Basic Hot the polymer/monomer mixing ratio was 2.5:1, and for Futura Basic Cold 10:7. The AgNps in the form of colloidal solution was added to the monomer of acrylic resin by volume proportion in 5, 10 and 20% concentration, excepting the control group specimens.

The powder and liquid with nanoparticles solution were mixed into a porcelain jar (fig.2c), then the acrylic resin paste was packed into the mold at the dough stage, the flask was closed and pressed. The polymerization technique was different, according to the manufacture recommendation. For the HCR the flask was immersed into a water bath and the temperature was rise up to 100°C, at 2-4 bar, during 20 min. For SCR reaction conditions have been 45°C, 2-4 bar, during 5 min. After polymerization the flask was opened and the specimens were removed from the investing material (fig. 2d).

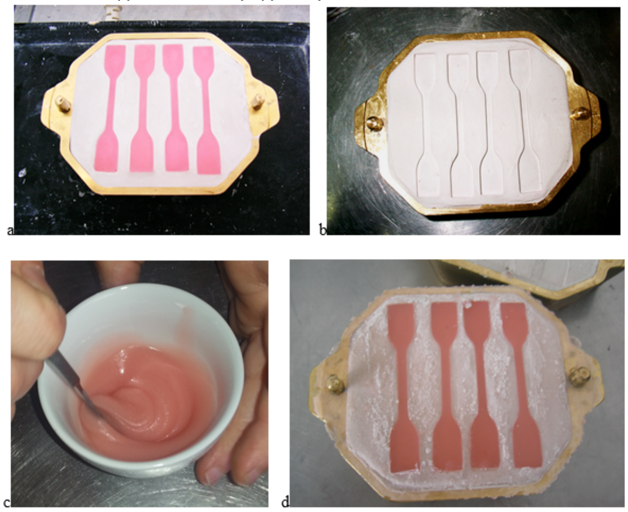


Fig.2. The preparation stages of the specimens

The specimens were washed with a stiff brush under running water to remove all gypsum traces, finished with fine carbide burs, polished to a smooth and glossy surface, and finally immersed in distilled water and stored at 37°C, for one week, before testing.

Tensile testing

Tensile tests were carried out at room temperature according to the ISO 527-1: 2000 standard, using a computer-controlled testing machine (Instron 3382) equipped with a dynamic clip-on strain gauge extensometer (Instron 2620-601) for direct strain measurement. The rectangular specimens were placed and fixed between the grips of the testing machine (fig.3).

The tensile load was applied at a crosshead speed of 1 mm/min. Young's modulus (the slope of a secant line between 0.05% and 0.25% strain on a stress-strain plot),

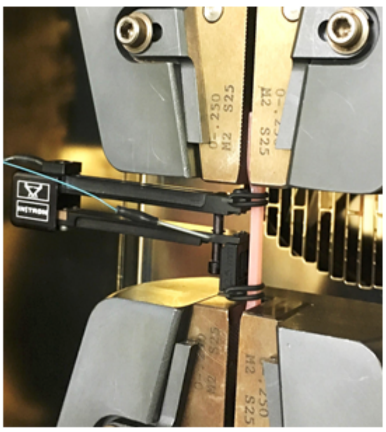


Fig.3. The specimen in the testing machine

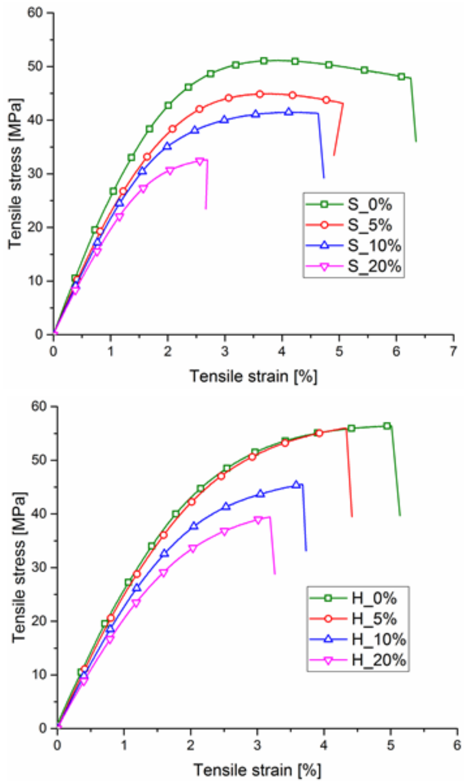


Fig. 4. Tensile stress vs. tensile strain for SCR and HCR samples

tensile yield (tensile stress at yield) and tensile strength (maximum tensile stress during the test) were determined.

Results and discussions

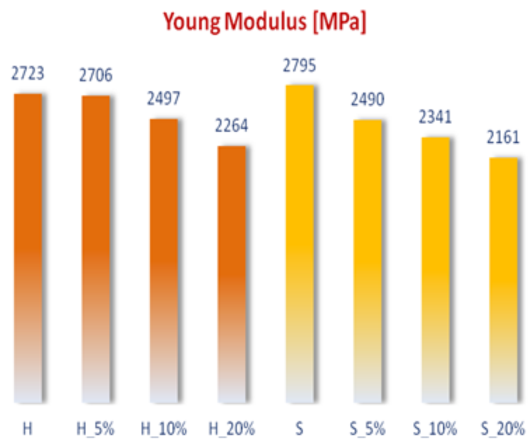
Tensile stress vs. tensile strain graphs for SCR and HCR samples are shown in figure 4.

As can be seen the behavior of the two groups are quite similar, and all specimens exhibit brittle fractures (typical flat crack at break). A progressive decreasing in mechanical properties when the amount of AgNPs increases is obvious (fig.4) but the evolution is different.

For HCR samples we noticed that increasing the AgNPs concentration leads to a constant decrease of all mechanical features (fig.5). The specimens with 5% AgNPs showed very similar mechanical properties with the control group.

For SCR samples we found a more pronounced decreasing of all mechanical features comparing to control group. It seems the lack of chemical bond between the inorganic material (AgNps) and polymer itself is the main cause of decreasing in mechanical properties which affects especially the SCR specimens.

The results of this study are similar with these of our previous research conducted through FEM analysis on the effect of AgNPs incorporation into the dental resin [12].



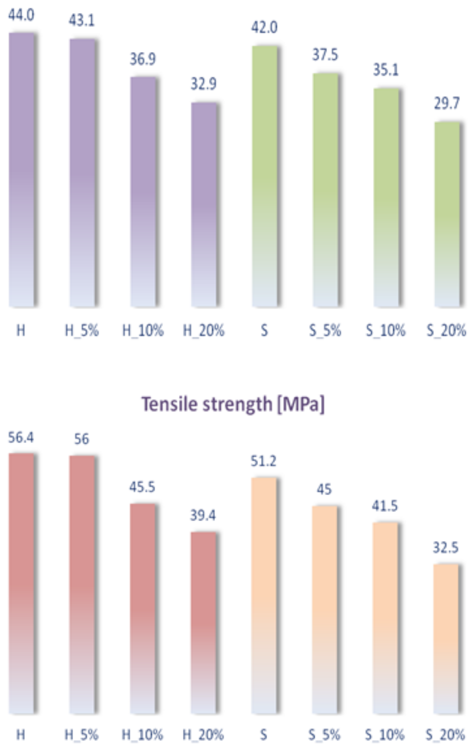


Fig. 5 Mechanical properties of the SCR and HCR samples

The addition of AgNps promotes antimicrobial activity, and there are studies that ilustrate that a very low concentration of silver [13-15] gave a good antibacterial performance.

In higher concentration AgNps incorporation do not affect cellular metabolism and do not cause genotoxic damage to cells [16] .

Conclusions

Our study illustrates that incorporating AgNps in acrylic resins decrease the rigidity of the materials. According to this research, for optimal mechanic properties, it is indicated a lower concentration of AgNPs.

Within the limitations of this study, the mechanical properties of acrylic resins were influenced by the concentration in AgNPs. The HCR specimens with 5% AgNps illustrated similar mechanical characteristics with the control group, so, this concentration can be successfully utilized with an optimal antimicrobial effect, without relevant modification of the resin parameters. The SCR specimens showed major changes of mechanical properties in relation to the control group.

Since this research was limited to one size of AgNps even for different concentrations, further studies are necessary to evaluate the effects of AgNps size on acrylic resin mechanical properties.

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