Change in the mechanical properties of nanosilver--modified acrylic resin

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Abstract

Introduction: Acrylic resins are very commonly used as the material for the production of partial mobile prostheses. Very frequently, microbial colonization of mobile dental prostheses occurs in patients as a result of manufacturing errors, improper hygiene, or systemic diseases. This, in turn, may favor the development of prosthetic stomatopathies. Attempts are made at discovery of novel materials with properties similar to those of acrylic resins as well as at modification of acrylic materials so that they inhibit the bacterial growth on the prosthetic surface and the surrounding tissues.
Objective: The objective of the study was to examine the change in the properties of acrylic resins modified by the addition of silver nanoparticles characterized by bactericidal and fungicidal activity.
Material and methods: Modification of heat-polymerized acrylic resins consisted in silver nanoparticles being added to the resin components at the liquid-to-powder mixing stage prior to polymerization. Thus-modified materials were used to manufacture test samples sized 20 x 10 x 2 mm with nanosilver concentrations of 0 ppm (control sample), 5 ppm, 10 ppm, 15 ppm, 20 ppm. Then, mechanical properties of the materials, including Brinell hardness, elastic modulus, and flexural strength was assessed by the four-point test.
Results: Brinell hardness, elasticity module, and flexural strength decreased with the increasing content of nanoparticles compared to the control sample. The differences ranged between 2 and 7% for flexural strength, 3 and 5% for elasticity modulus, and 12-15% for Brinell hardness.

Key words:

Acrylic resins, silver nanoparticles, nanosilver-modified acrylic resins, strength tests

Conclusions: As shown by the study results, modification of acrylic resin composition resulted in deterioration of the mechanical properties of the material. However, the search for other modifications having no detrimental impact on the mechanical properties of the material should be continued.

Introduction

Due to economic reasons, partial and total tissue-borne prostheses are the treatment of choice for Polish patients with extensive tooth loss. Such prostheses are also used as a temporary measure in dental implant treatment. Acrylic resin is the primary material used in the manufacturing of these prostheses. Actually, the term "acrylate resin" is more accurate from the chemical standpoint, as the substance is the methyl methacrylate, or methacrylic acid methyl ester. Despite numerous advantages of the material, certain drawbacks become evident even when proper laboratory and clinical preparation procedures are strictly followed.

Irritation caused by mechanical impingement of tissues by tissue-borne prostheses and other tooth-loss-filling elements may contribute to the development of infections. Concomitant systemic diseases and improper hygiene of dentures and mouth are sources of multiple problems encountered in everyday clinical practice of prosthodontics and periodontologists.

Certain properties of the acrylate material such as its porosity or residual monomer release are impossible to eliminate completely. Very frequently, microbial colonization of mobile dental prostheses occurs in patients as the result of manufacturing errors or improper hygiene measures. This, in turn, may favor the development of prosthetic stomatopathies. Attempts are made at discovery of novel materials with properties similar to those of acrylic resins as well as at modification of acrylic materials so that they inhibit the bacterial growth on the prosthetic surface and the surrounding tissues [1,2]. Modifying agents are commonly used with acrylic resins [3]. Examples include aluminum oxide of styrene-butadiene rubber being added to increase the mechanical strength of the material as much as 5 times [4].

In the pre-antibiotic era, silver was a popular infection-inhibiting agent. Also in modern-day medicine, it is used for this purpose in the form of nano-sized particles. Nanosilver was shown to be effective against numerous pathogens including *S. aureus, E. coli, A. baumani, E. fecalis, P. aeurginosa, S. epidermidis*, and *C. albicans*.

Numerous studies are under way to obtain bacteriostatic/bactericidal and candidostatic/candidocidal materials for use in prosthetic relinings, partial or total prostheses, crowns, obturators, dental guards and parts of orthodontic braces. The materials should maintain optimum aesthetic and mechanical parameters while simultaneously exerting the oligodynamic effects of silver [5]. In the future, such materials may be used in the prevention of oral infections in patients with mobile prostheses, particularly in infection-prone individuals such as patients with diabetes, patients with congenital immunodeficiency disorders or AIDS, immunocompromised patients, cancer patients, etc.).

Objective

The objective of the study was to examine the change in the properties of acrylic resins modified by the addition of silver nanoparticles characterized by bactericidal and fungicidal activity.

Material and methods

Nanosilver particles were added to the acrylic resin before thermal polymerization at the stage of liquid-to-powder mixing (Vertex). Thus-modified materials were used to manufacture test samples sized 20 x 10 x 2 mm with nanosilver concentrations of 0 ppm (control sample), 5 ppm, 10 ppm, 15 ppm, 20 ppm. Then, mechanical properties of the materials, including Brinell hardness, elastic modulus, and flexural strength as assessed by the four-point test.

Brinell hardness was determined using a HPK 8411 Brinell hardness tester. Differences in the hardness and elasticity of test samples were determined. The samples were impressed using a 5-mm sphere using the initial load of 9.81 N, with the depth of the impression (h) being measured in millimeters after 60 seconds of loading as well as 60 seconds after load removal. Microhardness was measured using the measured h values and the formula 63.69 x P/h; the results were expressed in MPa.

Elasticity was determined using the values of h, h0, and Young's modulus for elastic recovery of the material (h>h0). Tests were carried out using 3 samples with different nanosilver content as well as a control sample without the addition of nanosilver particles.

Flexural strength and elasticity modulus were tested using a Dynstat apparatus.

In vitro cytotoxicity was examined in a VERO cell line culture (European Collection of Cell Cultures, cat. no. ECACC 84113001) pursuant to the PN-EN ISO 10993-5 procedure.

Results

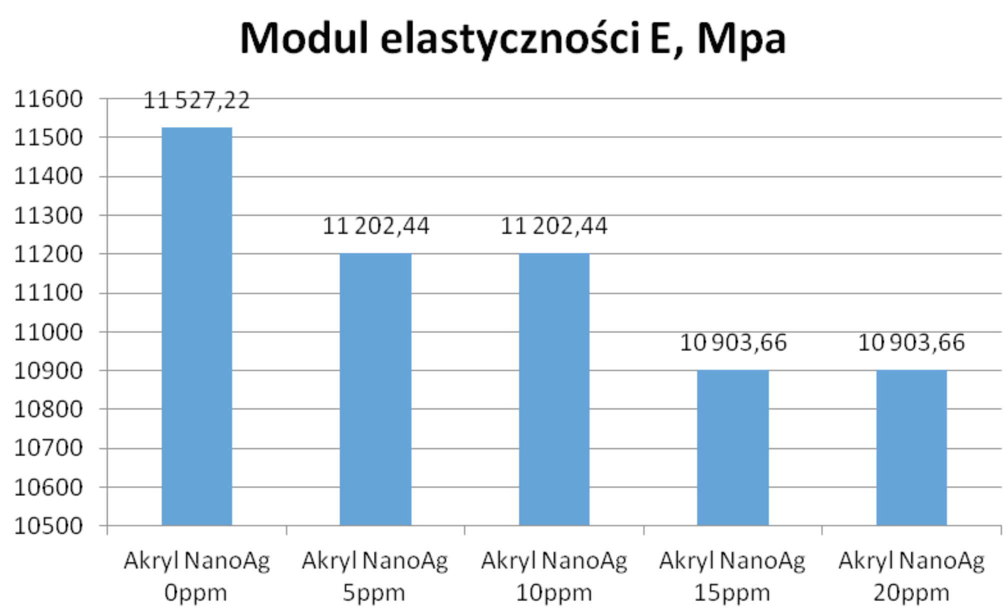
The results of the studies are presented in Tables 1-3. Increasing content of silver nanoparticles resulted in marked decrease in the elastic modulus, hardness, and flexural strength of the samples. The 15 ppm to 20 ppm increase had no effect on the Young's modulus and hardness.

A 3-5% decrease in Young's modulus was demonstrated for samples with the increased nanosilver content. Tensile strength tests were carried out using a Dynstat apparatus.

Discussion

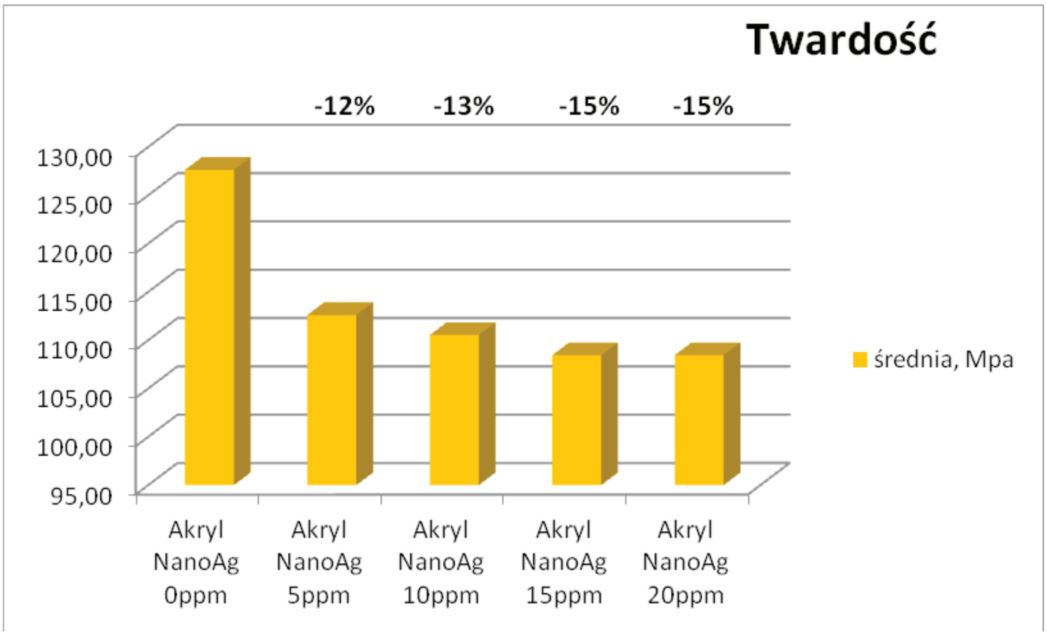
Studies by other authors confirm that incorporation of antibacterial/antifungal agents into the acrylic resin has negative effect on the mechanical strength of the material [6,7]. According to the reports, satisfactory antifungal activity is achieved for nanosilver levels in the range of 20-40 ppm. Studies are continued to determine the optimum content of silver nanoparticles in acrylic resins used for the manufacturing of mobile prostheses that would ensure appropriate antifungal and antibacterial activity while maintaining appropriate mechanical strength [8,9,10]. An increase in the mechanical strength of acrylic resins was reported for the addition of aluminum oxide; however, the compound had no antimicrobial effect [4]. In the reported cases, no desired antibacterial, antifungal, and antiviral effect could be achieved with nanosilver added at levels ensuring no significant impact on the resin strength.

Table 1.
Young's modulus vs. nanosilver content



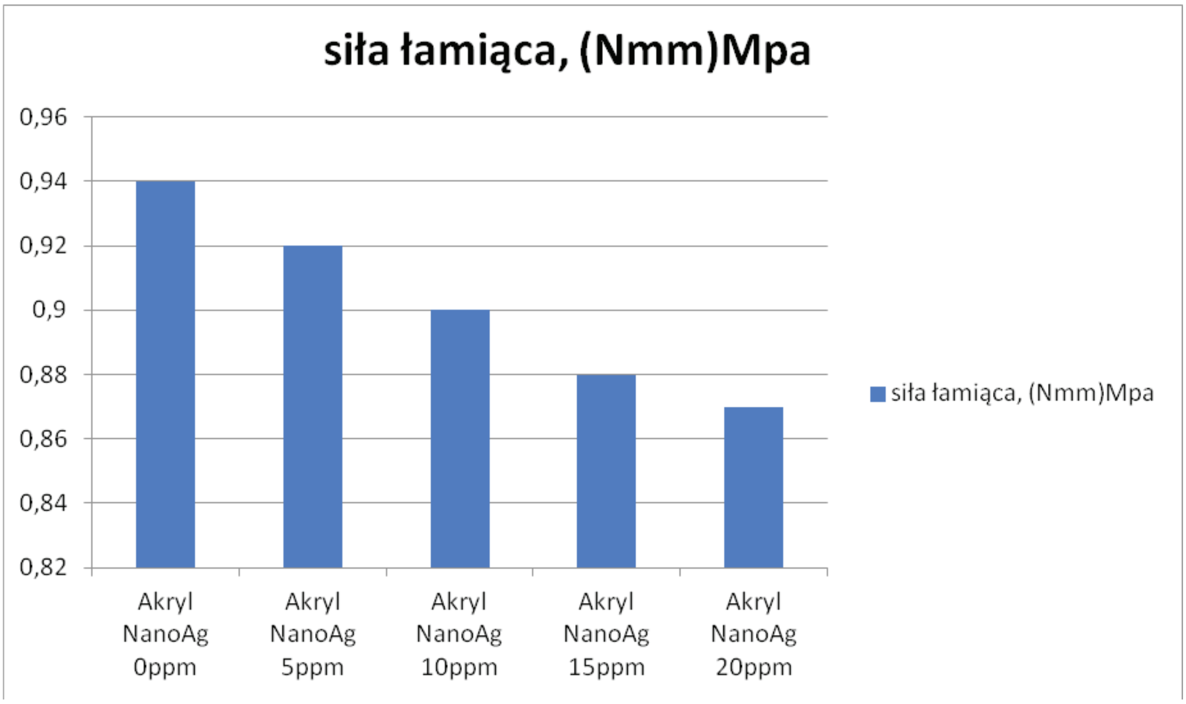
The Brinell hardness loss was 12-15%

Table 2.
Hardness (MPa) vs. nanosilver content



The flexural strength loss was 2-7%. Tested acc. to ISO 2039-1, February 2003

Table 3.
Breaking strength [N/mm^2 (MPa)] vs. nanosilver content



The flexural strength loss was 2-7%. Tested acc. to ISO 2039-1, February 2003

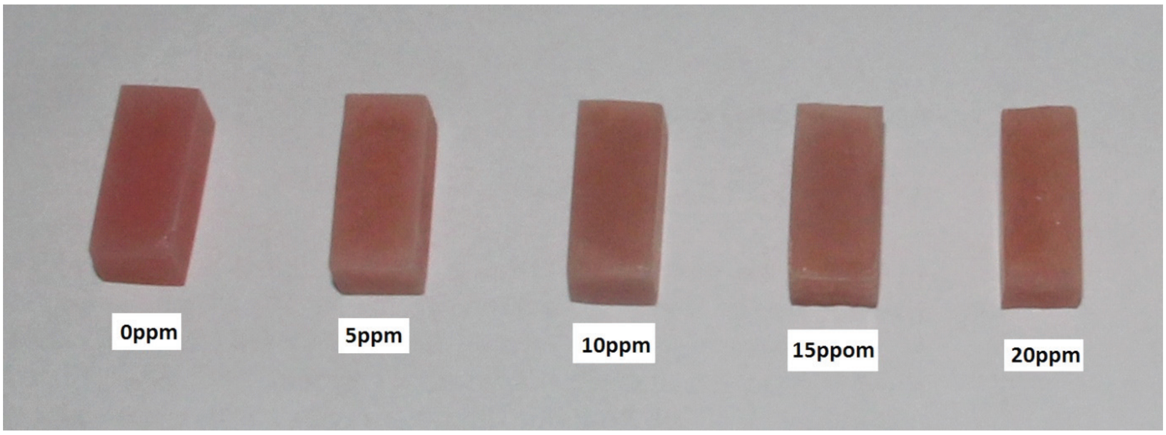


Fig. 1.
Test samples with silver nanoparticles at various concentration and the control sample.
The aesthetic qualities of the material were considered satisfactory.
ISO 10993-5 toxicity tests yielded negative results to demonstrate the safety of the material.

Conclusions

As shown by the study results, modification of acrylic resin composition resulted in deterioration of the mechanical properties of the material. However, the search for other modifications having no negative impact on the acrylic material structure, should be continued.

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