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GOLD-NANO PARTICLES ADDITION TO CONVENTIONAL HEAT CURED ACRYLIC RESIN MATERIALS: INFLUENCE ON THE FLEXURAL STRENGTH, COLOR CHANGES, SURFACE ROUGHNESS AND HARDNESS

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ABSTRACT

This study was intended at evaluating the impact of adding gold nanoparticles (AuNPs) on the characteristics of heat-cured acrylic denture base resin. Heat cured polymethyl methacrylate (PMMA) samplings, each one had a dimension of 50 mm length, 30 mm width and thickness of 0.5±0.1 mm, enclose various sizes (10 and 20 nm) of gold nanoparticles were formulated, where free nanoparticle samples were deemed as the control group (N=6 specimens for each group). Flexural strength, color changes, surface roughness, and hardness of all specimens were then assessed. Data were amassed, statistically evaluated, and tabulated. It was fulfilled that statistically significant decreases in the flexural strength were observed with the increase in gold nanoparticle size, where group 3 (with 20% nanogold particle size) was peaked. However, no significant differences in PMMA color changes, superficial roughness, and hardness were observed in the groups covering various sizes of AuNPs. It was concluded that The flexural strength of heat-cured PMMA-resin showed significantly decreases with the addition of AuNPs, particularly with the particle's sizes of 20nm.

KEYWORDS: Gold nanoparticles, Flexural strength, Color changes, Surface roughness, Hardness.

INTRODUCTION

In modern life that seeking for upgrading of people's livelihood requirements and elevation of oral health expertise; prosthodontics gradually sensed extensive notice. Prosthodontics is chiefly for dental deficiencies and treatments after tooth loss i.e., onlays, crowns, and dentures. The utilization of artificial prostheses is also involved in periodontal diseases, temporomandibular dual illness, and maxillofacial tissue deficiencies[1–4].

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PMMA-based resins are widely used in dentistry for a variety of purposes, including removable denture bases, artificial tooth manufacture, dentures, obturators, orthodontic retainers, temporary or provisional crowns, and dental prosthesis maintenance. Most of prosthetic acrylic resins contain PMMA and extra-copolymers. Auto-polymerizing acrylic resins have the benefit of quick and simple conducting, struggle to force breakage, high flexural intensity, and suitable thermal diffusivity which are the enviable characteristics of denture base acrylics. The idyllic denture base material ought to also own numerous crucial characteristics. [5-9]

Biocompatibility, good aesthetics, strong bond strength with current denture teeth, radiopacity, ease of repair, and acceptable physical and mechanical qualities are some of these properties. [10].

As a result, a wide range of additional materials, such as glass fibres, long carbon fibres, and metal wires, have been introduced into the PMMA polymer to enhance its physical and mechanical properties.

Nanotechnology mostly mentions to a major of pragmatic science and technology which uniting theme is the matter regulator on the atomic and molecular range. Nanoscience entails the research of materials on the nanoscale between 1 to 100nm. Polymer nanocomposite is the term used to describe a polymer that has nanoparticles dispersed within it[11]. The polymer nanocomposites' properties differ on the kind of integrated nanoparticles, namely their size, form, doses, and binding with the polymer matrix itself[12]. In this context,many efforts have been performed to integrate in organic nanoparticles into PMMA. PMMA/alumina nanocomposite was fabricated using alumina nanoparticles coated with acryloxypropyldimethyl methoxysilane, with better mechanical properties than the pure PMMA[13], for instance. CaCO3-nanoparticles altered with stearic acid was also integrated into PMMA to enhance the abrasion resistance of PMMA[14]. Moreover, BaSO4-nanoparticles were blended to PMMA to improve the radiopacity properties[15]. Recent studies have noted gold nano-particle blends with antibiotics enhanced the bactericidal properties of the end-materials[16, 17]. However, the mechanical qualities of the composite in the dental prosthesis are just as significant as the antibacterial properties, since during mastication it will be under a huge amount of pressure. The mechanical characteristics of PMMA may be affected by the addition of AuNps, as investigated here. [18]

The aim of this study was to evaluate and compare the impacts of numerous sizes of AuNPs-nanoparticles on the flexural strength, color changes surface roughness, and hardness of heat-polymerized acrylic resin. It was hypothesized that, including different sizes of AuNPs would have different effects on its flexural strength, color changes surface roughness, and hardness.

MATERIALS AND METHODS

Eighteen samples of acrostone mixed with AuNps these samples were divided into three groups

The specimens were categorized to three separate groups (N=6 specimens) for each group as follow:

Group 1: Heat cure acrylic resin without any addition of AuNps (control group).

Group 2: Heat cure acrylic resin with size 10nm of AuNps.

Group 3: Heat cure acrylic resin with size 20nm of AuNps.

The used PMMA was Acrostone Cross linked heat cured pink denture base-material, acquired from Acrostone manufacture, Egypt, Licensed by WHW, England. NanoXact Gold Nanospheres – PVP (Dried) sizes 10 and 20 nm was acquired from NanoComposix company 4878 Ronson Ct Ste J San Diego, CA 9211, USA.

Specimens' preparation

The PMMA powder to a monomer mixing ratio was 3:1 (v/v). AuNps was dissolved in polyvinylpyrrolidone (PVP). PVP, which helps to maintain the steadiness when particles are placed onto a substratumor lean film, was mixed with a ratio of 10% (v/v) to the total powder and monomer volume. AuNps was mixed with monomer just prior to powder/monomer mixing, packing, and curing. After that, 6mLof PVP-AuNps were added to 9 mL monomer, shacked well, and mixed with 45 mL powder (33.75 g).

All specimens of eachmaterial (N=6 specimens for each group) were prepared using the manufacturer's recommendation.Thus, each material was melded, stuffed in the mold by mingling and masking with two substance strips and glass slides to elude pore incorporation.(Fig. 1)

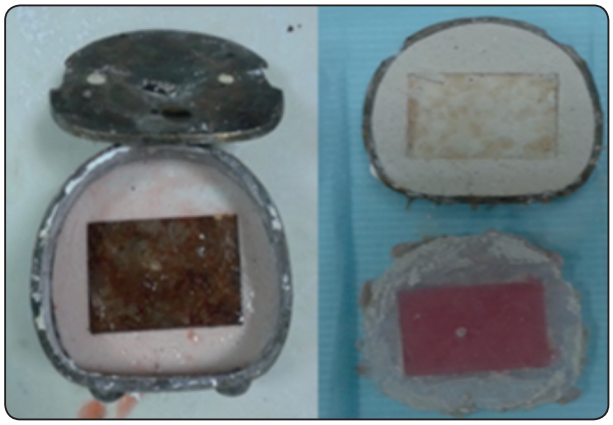

Fig. (1): The denture base PMMA specimens.

The specimens were taken out of the mould. After curing, and any remaining flashes were sensibly removed by grinding with wet 600-grit silicon carbide abrasive paper. All specimens were kept in dH2O at 37˚C for 24 hours after processing before being analysed.

Three separates' blends of heat cured pink denture base-material were mixed using manufacturer's guidelines and separately filled into the molds. The curing was done with a slow curing cycle for 8 h in Acrydig 10 curing unit, then de-flasked, finished, and polished.

Each specimen was checked using a dial calliper to ensure that it had a dimension of 50 mm in length, 30 mm in width and a thickness of 0.5 mm and a thickness of 0.5 ± 0.1mm, as well as a flat top and bottom surface, in accordance with ANSI/ADA Standard No. 139.

Measuring the surface microhardness

The specimen's surface microhardness was measured using Digital Display Vickers Micro-Hardness Tester (Model HVS-50, Laizhou Huayin Testing Instrument Co., Ltd. China) with a Vickers diamond indenter and a 20X objective lens (Fig 2). A load of 100g was employed to the specimen's surface for 20s. Three notches, which were regularly put over a circle and not closer than 0.5 mm to the adjoining indentations, were built on the surface of each specimen. The diagonals length of the indentations was measured by built in scaled microscope, and Vickers values were transformed to microhardness values. The microhardness calculation was attained using the following equation:

$$HV=1.854\ P/d^2 \qquad (1)$$

where, **HV** is Vickers hardness in Kgf/mm^2, **P** is the load in Kgf and **d** is the length of the diagonals in mm. (Fig 2)

Fig. (2) The digital display Vickers micro-hardness tester.

The surface roughness (Ra) was measured viaUSB digital surface profile gauge, (Elcometer 224/2, Elcometer Instruments, and United Kingdom), and the results were recorded using computer software of roughness tester supplier (Elcomaster 2 and Elcometer Instruments) (Fig 3). For every reading taken, the mean roughness value (Ra,um) was symbolized by the arithmetic mean between valleys itemized and the peaks. To enhance the filtering and undulation on the surface, a stretch of 2 mm in length with a cut-off of 0.25mm was employed after scanning the profilometer needle. Each surface was triplicated, always with the needle scanning of the geometric center of the specimen, beginning from three various points. The roughness of each specimen was calculated using the average of the three readings.

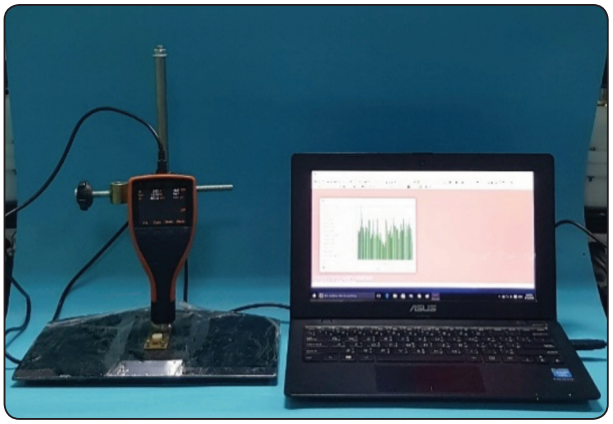

Fig. (3) The USB digital surface profile gauge, (Elcometer 224/2, Elcometer Instruments, and Great Britain).

The procedure of flexure strength test

These tests were accomplished using Bluehill Lite Software from Instron®. All samples were separately and horizontally fixed in a custom constructed load fixture [three point bend test assembly; two parallel stainless steel bars with span length of 50 mm supporting the specimen, and on the tensile side, the damage is centrally located.] on a computer regulated materials testing machine (Model 3345; Instron Industrial Products, Norwood,MA, USA) with a load cell of 5 kN and data were documented with the use of computer software (Instron® Bluehill Lite Software) (Fig 4). Then the samples were statically compressed til they fractured at a crosshead speed of 1 mm/min. The curves of the stress-strain were documented usingcomputer software (Instron® Bluehill Lite Software).FS signifies the regulating stress at which failure is imminent. The calculation value of FS was acquiredby the subsequent formula:

$$\mathbf{FS\ (ó) = 3F\ (L)/\ 2wh^2} \qquad (2)$$

where,**F** is the maximum load at the point of fracture, **L** is span, **w** is the width of the sample, and **h** its height.

Fig. (4) Computer-controlled materials testing machine.

Testing the specimens'color

The specimen's color was determined using a Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany) (Fig 5). The aperture size was set to 4 mm and the specimens were precisely aligned with the device. A white background was chosen, and quantities were made using the CIE L*a*b* color space comparative to the CIE standard illuminant D65. The color changes

(ΔE) of the specimens were assessed using the next formula:

$$\Delta E = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{½} \quad (3)$$

where, L* = Lightness (0-100), a* = (alteration the color of the axis red/green), and b* = (color difference axis yellow/blue)[19].

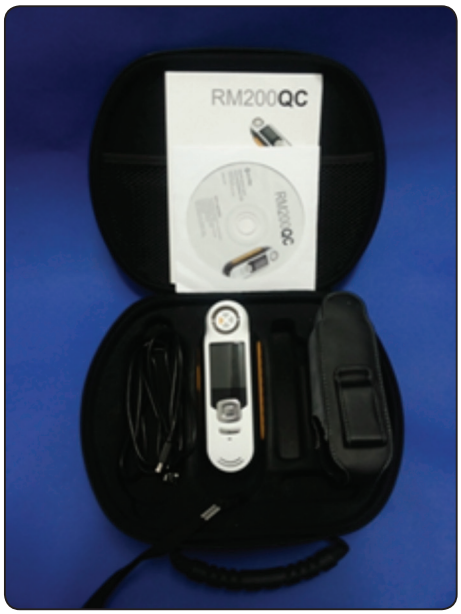

Fig. (5) Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany).

Statistical analysis

Data was analyzed using SPSS ver. 26 (IBM, Inc., Chicago, IL, USA). Data were revealed as mean and standard deviation. Student's t-test was used to relate among quantitative parametric data of two different groups, while One-way analysis of variance (ANOVA) and Tukey were benefitted for comparing quantitative parametric data of more than two different groups. The P value <0.05 was believedstatistically significant.

RESULTS

This study has shown that there was a statistically significant decrease in the flexural strength, with the highest reduction observed in group 3 (with 20% nanogold particle size). However, no significant differences in PMMA color changes, surface roughness and hardness were observed in the groups containing different sizes of AuNPs.

TABLE (1) Shows the mean values for the surface microhardness, surface roughness, flexure strength and color changes for the three groups.

Properties	Control	Gr_10%	Gr_20%	P
Surface microhardness	**38.85 ±1.24**	**39.93 ±1.25**	**39.94 ±.60**	**0.16**
Surface roughness (RA)	**0.259 ±0.002**	**0.261 ±.001**	**0.259 ±.003**	**0.5**
Flexure strength (Mpa)	**59.55 ±19.51**	**42.84 ±10.41**	**35.13 ±5.20[b]**	**0.017***
DE	.	**19.66 ±3.21**	**20.89 ±3.69**	**0.55**

Data extractedas Mean±SD, *: significance ≤0.05, a: Significance between control andGr_10%, b: Significance between control andGr_20%, c: Significance between Gr_10% andGr_20%.

DISCUSSION

This study was designed to evaluate the influence of gold nanoparticles adding to conventional acrylic resin materials on their flexural strength, color changes, surface roughness, and hardness. The hypothesis was partially accepted for the tested properties, where PMMA flexural strength significantly declined with the addition of AuNPs.

Biocompatible materials are essential because denture bases come into close touch with the oral mucosa, preventing hypersensitivity and the emission of toxic substances in clinical situations [20]. The sizes of the selected AuNp particles for the present study were of 10 and 20nm for group 2 and 3, respectively, agreeing with the study disclosed that gold nanoparticles with size of 1-2 nm have very toxic effects, whereas many studies have reported AuNPs with size ranging between 14 and 100 nm have no cytotoxic effects in mammals[21,22-24].

The microhardness control, which refers to the material's resistance to permanent surface indentation or penetration, is appreciated because a dental material with a higher surface hardness could tolerate more wear from a denture cleaner, tooth-brush, or food. [25].

The present study exhibited that adding gold nanoparticles increased the Vickers microhardness of their composite with PMMA, showing the possible correlation between microhardness and flexural strength. Particularly, AuNps have likely declined the defects size which formerly occurred in the PMMA matrix, thus increasing the microhardness, and decreasing the flexural strength. smoother denture base materials are more stain-resistant, more aesthetic, and have less Candida albicans adherence and microbial colonisation. [26].

Plaque formation and microorganism colonisation may increase above the clinically acceptable level of intaglio surface roughness of the denture base, which is 0.2 μm. [27]. These findings are agreed with the present study that displayed a clinically accepted values for surface roughness for all groups.The reason may be related with the acceptable spreading of nanoparticles within resin matrix, alongside with their ability to fill the places among the polymer chains, resulting in fewer nanoparticles on the specimens' surface.

Flexural strength reveals the material ability to repel the crack initiation during the bending force action that appears during the act of mastication [28]. For this cause, the denture base should have adequate flexural strength and elastic modulus to repel the fracture creation.[29].

Our results noticed that there is a statistically significant decrease in the flexural strength for the experimental groups, where group 3 (with 20% nanogold particle size) was bottomed, and a significant difference with the control group was found, confirming our hypothesis about flexural strength measurements.These outcomes are also agreed with a former study which revealed that the incorporation of AuNps with different concentrations into heat polymerized PMMA resin decreased the flexural strength [30].

It was implied that, The amount of unreacted monomer could be increased by adding nanoparticles, and it worked as a plasticizer. [31]. Taken together ,when the conversion degree of acrylic resin is reduced and the residual monomer amount is increased, the material's mechanical characteristics are reduced. The nanoparticles in the polymer matrix could behave as contaminants, altering the physicochemical characteristics of polymers and causing chemical binding of the C=O groups to change, decreasing the material's mechanical characteristics. As a result, the finished product is more breakable than pure resin. [32,33]. Again,when nanoparticles are mixed with monomers or polymers, the nanoparticles may amass into large clusters, negatively affecting the nanocomposite characteristics[34-35]. It has been suggested that this may be due to the concentrations of stress at the agglomeration sites [35].

Based on our achieved results, adding gold nanoparticles (with sizes of 10 and 20nm, for group 2 and 3, respectively), resulted in non-significant difference in color change. The present results were in accordance with the study that the Flowable dental composite SDR (Dentsply, United Kingdom) modification by nanogold, nanosilver, and silica, gave a slightly lighter color change appearance [36].

CONCLUSION

In summary, the effect of gold NPs on some properties of conventional heat cured acrylic denture base material was investigated.It was found that, PMMA flexural strength significantly declined with the addition of AuNPs, the decrease in PMMA flexural strength was greater with the addition of 20nm AuNPs compared to 10nm AuNPs, No significant differences in PMMA color changes, surface roughness, and hardness were observed in the groups covering different sizes of AuNPs.

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