EGYPTIAN
DENTAL JOURNAL

Vol. 64, 1825:1836, April, 2018

I.S.S.N 0070-9484

Fixed Prosthodontics, Dental materials, Conservative Dentistry and Endodontics

www.eda-egypt.org • Codex : 241/1804

EFFECT OF INCORPORATION OF SILVER NANO-PARTICLES ON THE REPAIRABILITY OF CONVENTIONAL AND MICROWAVE DENTURE BASES

Muhamad A. Samman*, Azza A. Segai** *and* Saad S. El-Ghazawy***

ABSTRACT

Background: Repeated fracture of denture base is a common problem in prosthodontics, it represents an annoyance for the clinician. Therefore, the possibility of increasing repairability using new reinforcement materials is of great interest to prosthodontists.

Aim of the study: This study aimed to evaluate the effects of incorporation of silver nano-particles on the flexural strength of repaired polymethylmethacrylate (PMMA) and microwave denture bases.

Materials and methods: thirty-six specimens of conventional and microwave denture base materials were fabricated (18 for each) and divided into three subgroups according to surface design (Dovetail, 45° bevels and butt joints). Silver nano-particles was added to repair cold cure-acrylic resin powder. A three - point bending test was used to measure flexural strength. The results were analyzed with a P-value of <0.05 being significant.

Results: totally it was found that repaired Microwave group recorded statistically non-significant (p>0.05) higher flexure strength mean value. Silver nano-particles modified cold cure repaired subgroup recorded statistically significant (p<0.05) higher flexure strength mean value than cold cure repaired subgroup mean value. The difference between repair surface design subgroups was statistically non-significant (p>0.05).

Conclusion: Incorporation of silver nano-particles into the repair resin improved the flexural strength of repaired denture base

KEYWORDS: Denture repair, flexural strength, impact strength, PMMA, microwave, silver nano-particles

* Assistant Professor, Dental Biomaterials Department, Faculty of Dental medicine, Al-Azhar University, Egypt
** Assistant Professor, Removable Prosthodontics Department, Faculty of Dentistry, Tanta University, Egypt
***Lecturer, Dental Biomaterials Department, Faculty of Dental medicine, Al-Azhar University, Egypt

INTRODUCTION

Poly methyl methacrylate (PMMA) resin was introduced in 1937 by "Walter Wright". It has been the most widely used denture base material ever since it was introduced. Despite the excellent properties of the material, due to its ease of fabrication and adjustment, low cost, and possibility of repair, acrylic resin denture bases have got some inherent shortcomings such as frequent fracture of dentures because of fatigue, low thermal conductivity, and ease of microbial adherence to the intaglio surface.[1]

For polymerization of acrylic resins, various curing techniques and denture base materials containing modifications of PMMA have been developed. The conventional method of processing denture base polymers is done in a water bath by polymerizing the dough molding of monomer and polymer. Other processing techniques used are microwave energy or light curing. [2] Although the conventional method has been considered as the best means of processing heat-cured denture resins, it takes relatively long time to cure the material, and also it is not a very clean procedure. The processing of denture with microwave is quite cleaner, less time taking, homogeneous mix of the material with excellent adaptation, and less residual monomer. [3]

The factors which influence the fracture of acrylic resin dentures include stress intensification and increased ridge resorption, leading to unsupported dentures, deep incisal notching at the labial frenum, sharp changes at the contours of the denture inclusions previous repair and residual methyl methacrylate (MMA). [4] Fabrication of a new removable prosthesis is highly costly and time-consuming for both patients and prosthodontists. Therefore, denture repair is required if the denture fits properly. The proper denture repair procedure should be easy, time saving, match the original color, maintain dimension accuracy, and restore original strength. [5]

Several materials have been used to repair fractured acrylic resin, including auto polymerized acrylic resin and visible light-polymerized resin. Auto polymerized resin is the repair material most commonly employed. Unfortunately, its strength has been shown to range from 18 to 81% of intact heat-polymerized denture resin. [6] Repairs with visible light polymerized resin result in even lower final strengths. [7]

To achieve adequate repair strength, many attempts have been made to modify repair surface design and/or reinforce the repair resin. Different design modifcations of repaired joints have been made by increasing the surface area, which therefore improves the bond strength. [5, 8, 9]

Silver is a metal with high conductivity; its antimicrobial properties have been reported in several studies when added to the denture base in the form of nano-particles.[9, 10, 11] However, the effect of incorporation of silver nano-particles (AgNPs) on flexure strength of repaired denture base materials has not been verified.

Therefore, the aim of the present study was directed to evaluate the effect of incorporation of silver nano-particles (AgNPs) on flexure strength of repaired denture base materials processed by two techniques - conventional water bath technique and using microwave energy different repair surface design

The null hypothesis of the study was (a) there was no difference in the repaired flexural strength of PMMA denture base resin polymerized by conventional curing method and polymerized by microwave technique (b) the addition of AgNPs will not improve the flexural strength of repaired PMMA denture bases.

MATERIALS AND METHODS

Materials:

Two different denture base materials were used to construct Conventional heat cured denture base. (18 samples).

Microwave polymerized acrylic resin samples

Table (1) and table (2) show materials and devices used throughout the study

Intact samples were fractured and prepared for repairing with different design (Dovetail, Bevel, Butt design 90 degree).: Different repair site design used in the study were described in table (3)

Two repair materials were used to repair fractured samples with different designs:

a) Self-cure acrylic resin.

b) Self-cure acrylic resin modified with silver nano-particles.

Table (1) Materials used in the study

Denture base material	Manufacturer
Conventional heat cured acrylic resin	Vertex-entabyJ. V. Oldenbameveltin 623705 HJ Zeist the Netherlands.
Microwave polymerized acrylic resin	ECO-CRYL M, Protechno, made in Spain.
Silver nano-particles	Nano Tech Egypt for Photo-Electronics.
Self-cure acrylic resin	Acrostone cold cure, Egypt.

Table (2) Devices used in the study

Name	Manufacturer
Conventional metal flask	Dentsply.
Conventional curing machine.	Dentsply.
Universal Testing Machine	(Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK).
Microwave flask	Protechno, Spain.
Microwave curing	Protechno, Spain.

TABLE (3): Different repair site design used in the study

Repair design	Description
Dovetail	Dovetail shaped grooves were made on joint surfaces of either segments.
Bevel	length of 31.25 mm for the lower surface and 30 mm for the upper surface with a 45° bevel, width = 10.0 ± 0.01 mm, and thickness = 2.5 ± 0.01 mm[12]
Butt	length = 31.25 mm, width = 10.0 ± 0.01 mm, and thickness = 2.50 ± 0.01 mm[12]

Methodology.

Preparation of experimental Specimens.

I. Flexure strength samples preparation:

Standard samples were fabricated, according to ISO 1567=1999 specification.

Mould construction:

Specially designed metallic rod was fabricated with the following dimension (2mm thickness, 10mm width and 65 mm length) to makes standard rectangular mold cavity in stone for acrylic samples fabrication, according to ISO 1567=1999 specification .

According to curing and processing methods samples were divided into two main groups:

Group (I): Eighteen samples from conventional heat cure acrylic resin.

Group (II): Eighteen samples from microwave cure acrylic denture base resin.

Construction of flexure strength samples.

Preparation of stone mold for conventional heat cured acrylic resin samples:

Using investing plaster in conventional flask, standardized mold cavities were constructed with metallic rod (2mm x 10mmx 65 mm dimensions) according to ISO 1567=1999 specification. Wax pattern construction: the resultant mold cavity was filled with wax pattern in the flask, that flasked using investing plaster in conventional flask. Flasking: Each flask pour was allowed to set for 1 hour. A thin film of sodium alginate Separating medium was applied to the surface of investing material. Elimination of wax: The flask was placed in boiling water for 5 minutes to soften the wax. Then the two halves of the flask were separated, and wax was eliminated. Each half of flask was thoroughly flushed with 3 applications of hot house hold detergent solution (2 teaspoonful of Nirma powder in 1 - liter Water) followed by rinsing in lean boiling water.

Application of Separating medium: Upper and lower halves of flask were dried, and separating medium was applied to investing surface of both halves of flask with camel hair brush when mould was warm.

Mixing of polymer and monomer: (According to manufacturer's recommendations) the mix of resin prepared using ratio of 4 ml. Monomer liquid to 10 grams of powder.

Packing of acrylic resin: When the resin reached the dough stage the resin dough was placed into the mold cavities section of the flask using stainless steel spatula, and the two sections of the flask were closed together. The flask was placed in the bench press and closed gradually. Curing cycle: (according to manufacturers instructions) the flask was immersed into water at 74 °C was maintained for 1.5 hours then water bath temperature was brought to 100 °C and allowed to boil for 1 hour. The flask is then cooled slowly to permit release of stresses within the polymer.

De-flasking: the investing plaster was removed carefully then the acrylic block was removed from the flask, finished and polished.

Preparation of stone mold for Microwave cured acrylic resin samples Flasking: A specially fabricated fiber reinforced plastic flask was used for microwave curing**.** The flasking procedure for microwave processing is similar to that of conventional techniques. The wax patterns were flasked using investing stone in FRP flask. Each flask pours allowed to set for 1hr. A thin film of Sodium alginate Separating medium was applied to surface of investing material.

Elimination of wax: The FRP flask was placed in microwave oven with a high-power setting for 1 min. to soften the wax. Then the flask was separated, and softened wax was removed all in one piece. Each half of flask was then thoroughly flushed with 3 applications of hot household detergent solution and rinsed in clean boiling water.

Application of Separating medium: Separating medium (cold mold seal) applied to dried surface of investing medium of the both halves of flask with a camel hair bush when it was warm.

Mixing of polymer and monomer: The mix of PMMA resin was prepared with standard powder liquid ratio as recommended by manufacture. That is 4 ml. of liquid to 10 gm of powder. The necessary amount of liquid was taken in a mixing jar and then powder was added to liquid while tapping **the** jar until **the** layer of excess liquid disappeared. The lid was closed until mixture reached dough stage that is when resin separated cleanly from walls of mixing jar. The acryl is packed as conventional method.

Microwave curing cycle: Resin was microwave irradiated for 3 minutes at 495 W. De-flasking, the investing plaster was removed carefully then the denture removed from the flask, finished and polished.

Silver nano-particles modified self-cure acrylic resin

Preparation of silver nano-particles.

Manufacture method:

Silver nano-particles have been prepared by chemical reduction method as reported by Pal et al [13]. Silver nano-particles were prepared by microwave irradiation of silver nitrate ($AgN0_3$) solution in ethanol medium using PVP as a stabilizing agent.

Ethanol was observed to act as a reducing agent in the presence of microwave.

Properties:

Appearance (color): Yellow.

Appearance (form): Liquid.

Concentration: 300 ppm (0.3mg/ml) AgNPS. *Solubility:* Water, Ethanol Soluble.

Optical prop (Abs): ymax =414nm.

Flexure strength test procedure:

To determine flexural strength, fracture load was measured using a three- point bending test on universal testing machine (Instron 3345; Instron Co., Norwood, MA, USA) with acrosshead speed of 5 mm/min until fracture and data were collected at fracture load. The specimens were placed on a three- point flexure apparatus with a 50 mm distance between the two supports. The flexure strength was calculated from the equation;

$$\sigma = \frac{3\,F\,l}{2\,b\,h^2}$$

Where F**:** is the maximum load (N) exerted on the specimen, l**:** is the distance (mm) between the supports, b**:** is the width (mm) of the specimen, and h**:** is the thickness (mm) of the specimen. Data were recorded and collected.

Fig. (1) Flexure strength test sample loaded onto universal test machine.

Repair Procedure:

Then, all denture groups samples (I &II) were prepared for repair and divided into two subgroups:

GROUP (I) Conventional heat cure acrylic resin was divided into two subgroups:

- **Subgroup (A)**: Nine samples repaired with self-cure acrylic resin, with different designs (Dovetail, Bevel, Butt design 90 degree with n=3 for each).
- **Subgroup (B)**: Nine resin repaired with self-cure acrylic resin modified with Nano-silver, with different designs (Dovetail, Bevel, Butt design 90 degree with n=3 for each).

Group (II) microwave cured acrylic resin were divided into two subgroups;

- **Subgroup (A)**: Nine microwavable denture base resin repaired with Self cure acrylic resin, with different designs (Dovetail, Bevel, Butt design 90 degree with n=3 for each).
- **Subgroup (B)**: Nine microwavable denture base resin repaired with self-cure acrylic resin modified with Nano-silver, with different designs (Dovetail, Bevel, Butt design 90 degree with n=3 for each).
- **Silver nano-particles incorporation to repair self-cure acrylic resin;** using electronic analytical balance (Sartorius, Biopharmaceutical and Laboratories, Germany) with an accuracy of 0.0001-gram, pre-weighed Silver nano-particles (0.50 wt%) [24] were added separately to repair self-cure acrylic resin powder and thoroughly mixed with mechanical mixer to ensure distribution of nano-particles. Repair surfaces were painted with monomer, remounted into mold to preserve the required repair space. Repair resin powder with /out silver nanoparticles and monomer liquid was mixed as per the manufacturer recommendations and packed into the mould when the mix reached the dough consistency with slight overfilling. Then the flask was closed and a pressure of 4 lbs was applied

and bench cured for 30 minutes then the acrylic block was removed, finished and polished

- After repair, all samples were three- point loaded again by universal testing machine and flexure strength was calculated as mentioned before.

The statistical Analysis:

The results were recorded, tabulated and analyzed statistically. The means, standard deviations, ANOVA test and student t-test were carried out to assess the differences between the different groups. Statistical analysis was performed using Graph-Pad Instat statistics software for Windows (www.graphpad.com). P values ≤0.05 are considered to be statistically significant in all tests.

RESULTS

The mean values and standard deviation (SD) of flexure strength test results for both repaired ***Microwave*** and ***Conventional*** denture base material groups as function of repair surface designs and repair materials are summarized in table (4) and graphically drawn in figure (2).

For *Microwave* group;

In cold cured repaired subgroups; It was found that ***Bevel*** design subgroup recorded the highest flexure strength mean value (45.78±2.3 MPa) followed by ***butt*** surface design subgroup mean value (21.45±1.7 MPa) while ***Dove***tail design subgroup recorded the lowest flexure strength mean value (12.52±2.03 MPa). The difference between all groups was statistically significant as indicated by one way ANOVA (P=0.0001<0.05).

In AgNP modified cold cured repaired subgroups; It was found that ***Butt*** surface design subgroup recorded the highest flexure strength mean value (45.45±1.5 MPa) followed by ***Dove***tail design subgroup mean value (39.33±6.7 MPa) while ***Bevel*** design subgroup recorded the lowest flexure strength mean value (26.81±4.8 MPa).The difference between all groups was statistically significant as indicated by one way ANOVA (P=0.0019<0.05).

Cold curing vs. AgNP modified cold cured repair

With ***Dove***tail design; It was found that ***AgNP modified cold cured repaired*** subgroup recorded statistically significant higher flexure strength mean value (39.33±6.7 MPa) than ***cold cured cure repaired*** subgroup mean value (12.52±2.03 MPa) as indicated by t-test(t value = 6.5, p value =0.0002< 0.05)

With ***Bevel*** design; It was found that ***cold cured cure repaired*** subgroup recorded statistically significant higher flexure strength mean value (45.78±2.3MPa) than ***AgNP modified cold cured repaired*** subgroup mean value (26.81±4.8 MPa) as indicated by t-test(t value = 6.04, p value =0.0003 < 0.05)

With ***Butt*** design; It was found that ***AgNP modified cold cured repaired*** subgroup recorded statistically significant higher flexure strength mean value (45.45±1.5 MPa) than ***cold cured cure repaired*** subgroup mean value (21.45±1.7 MPa) as indicated by t-test (t value = 17.7, p value =<0.0001< 0.05)

Totally with microwave group AgNP modified cold ***cured cure*** repair was non-significant (p>0.05) higher than cold cured repair one. Also there was non-significant difference between surface designs (p>0.05) where (Bevel ≥ Butt ≥ Dovetail)

For *Conventional* group;

In cold cured repaired subgroups; It was found that ***Dove***tail design subgroup recorded the highest flexure strength mean value (30.23±3.7 MPa) followed by ***Butt*** surface design subgroup mean value (28.53±1 MPa) while ***Bevel*** design subgroup recorded the lowest flexure strength mean value (28.09±0.4 MPa).The difference between all groups was statistically non-significant as indicated by one way ANOVA (P=0.5010>0.05).

In AgNP modified cold cured cure repaired subgroups; It was found that ***Bevel*** design subgroup recorded the highest flexure strength mean value (30.313±1.8 MPa) followed by ***Dove***tail design subgroup mean value (30.31±1.9 MPa) while ***Butt*** surface design subgroup recorded the lowest flexure strength mean value (26.89±0.8 MPa). The difference between all groups was statistically non-significant as indicated by one way ANOVA (P=0.2757>0.05).

Cold curing vs. AgNP modified cold cured repair

With ***Dove***tail design; It was found that ***AgNP modified cold cured cure repaired*** subgroup recorded statistically non-significant higher flexure strength mean value (30.31±1.9 MPa) than ***cold cured cure repaired*** subgroup mean value (30.23±3.7 MPa) as indicated by t-test (t value = 0.0346, p value =0.973 > 0.05)

With ***Bevel*** design; It was found that ***AgNP modified cold cured cure repaired*** subgroup recorded statistically non-significant higher flexure strength mean value (30.313±1.8MPa) than ***cold cured cure repaired*** subgroup mean value (28.09±0.4 MPa) as indicated by t-test (t value = 1.95, p value =0.087 > 0.05)

With ***Butt*** design; It was found that ***cold cured cure repaired*** subgroup recorded statistically non-significant higher flexure strength mean value (28.53±1 MPa) than ***AgNP modified cold cured repaired*** subgroup mean value (26.89±0.8 MPa) as indicated by t-test (t value = 2.1, p value =0.064 > 0.05)

Totally with conventional group AgNP modified cold ***cured cure*** repair was non-significant (p > 0.05) higher than cold cured repair one. Also there was non-significant difference between surface designs (p > 0.05) where (***Dove***tail ≥ Bevel ≥ Butt)

TABLE (4) Flexure strength (MPa) test results (Mean ± SD) for repaired ***Microwave*** and ***Conventional*** denture base material groups as function of repair surface designs and repair materials

Variables		***Microwave group***		***Conventional group***	
		Cold cure	***AgNP modified***	***Cold cure***	***AgNP modified***
Surface design	***Dove***	12.52 ±2.03	39.33±6.7	30.23±3.7	30.31±1.9
	Bevel	45.78 ±2.3	26.81±4.8	28.09±0.4	30.313±1.8
	Butt	21.45 ± 1.7	45.45±1.5	28.53±1	26.89±0.8
ANOVA	***P value***	<0.0001*	0.0019*	0.5010ns	0.2757ns

Ns; non-significant (p > 0.05) ****; significant (p < 0.05)***

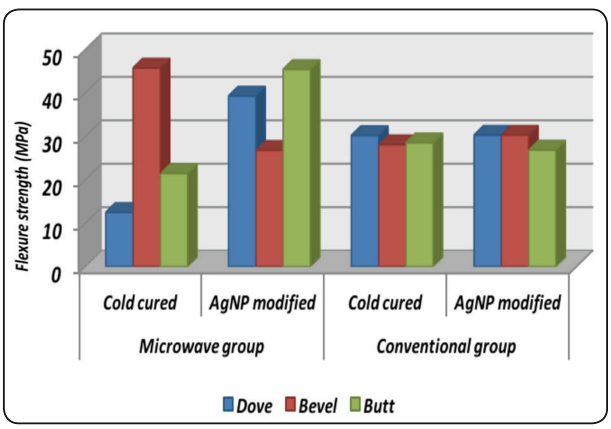

Fig. (2) Column chart of flexure strength (MPa) mean values for repaired ***Microwave*** and ***Conventional*** denture base material groups with different repair surface designs and repair materials

***Microwave* vs. *Conventional* repaired material groups**

With ***Dove***tail tail design; it was found that ***repaired Conventional*** group recorded statistically significant higher flexure strength mean value (30.23±3.7 MPa) than ***repaired Microwave*** group mean value (12.52±2.03 MPa) as indicated by t- test (t value = 7.1, p value =0.0001< 0.05)

With ***Bevel*** design; It was found that ***repaired Microwave*** group recorded statistically significant higher flexure strength mean value (45.78±2.3MPa) than ***repaired Conventional*** group mean value (28.09±0.4 MPa) as indicated by t-test (t value = 13, p value =< 0.0001< 0.05)

With ***Butt*** design; It was found that ***repaired Conventional*** group recorded statistically significant higher flexure strength mean value (28.53±1 MPa) than ***repaired Microwave*** group mean value (21.45±1.7 MPa) as indicated by t-test (t value = 5.96, p value = 0.0003 < 0.05)

Totally with cold cured repair conventional group was non-significant (p > 0.05) higher than microwave one. Also there was non-significant difference between surface designs (p > 0.05)

Microwave vs. Conventional repaired material groups

With ***Dove***tail design; It was found that ***repaired Conventional*** group recorded statistically non-significant higher flexure strength mean value (39.33±6.7MPa) than ***repaired Microwave*** group mean value (30.31±1.9 MPa) as indicated by t-test (t value = 2.2, p value =0.059 > 0.05)

With ***Bevel*** design; It was found that ***repaired Conventional*** group recorded statistically non-significant higher flexure strength mean value (30.313±1.8 MPa) than ***repaired Microwave*** group mean value (26.81±4.8 MPa) as indicated by t-test (t value = 1.1, p value = 0.284 > 0.05)

With ***Butt*** design; It was found that ***repaired Microwave*** group recorded statistically significant higher flexure strength mean value (45.45±1.5MPa) than ***repaired Conventional*** group mean value (26.89±0.8 MPa) as indicated by t-test(t value = 18.4, p value =<0.0001< 0.05)

Totally with cold cured repair microwave group was non-significantly (p > 0.05) higher than conventional one. Also there was non-significant difference between surface designs (p > 0.05)

Total effect of denture base material

Regardless of repair material or repair surface design, totally it was found that ***repaired Microwave*** group recorded statistically non-significant higher flexure strength mean value (**31.89±4.73** MPa) than ***repaired Conventional*** group mean value (**29.06±1.32**MPa) as indicated by three way ANOVA test (p value =0.297> 0.05)

Total effect of repair material

Regardless of denture material or repair surface design, totally it was found that ***AgNP modified cold cured repaired*** subgroup recorded statistically significant higher flexure strength mean value (**33.18±2.6** MPa) than ***cold cured cure repaired*** subgroup mean value (**27.77±3.78** MPa) as indicated by three way ANOVA test (p value = 0.0154 < 0.05)

Total effect of repair surface design

Regardless of denture material or repair material, totally it was found that ***Bevel*** design subgroup recorded the highest flexure strength mean value (**32.75±5.2**MPa) followed by ***Butt*** surface design subgroup mean value (**30.59±5.9**MPa) while ***Dove***tail design subgroup recorded the lowest flexure strength mean value (**28.09±6.2** MPa). The difference between ***repair surface design*** subgroups was statistically non-significant as indicated by three-way ANOVA test (p value = 0.7126 > 0.05)

DISCUSSION

Heat-polymerized acrylic resin has been the most common denture base material. However, the mechanical strength of acrylic resin is not sufficient to maintain the longevity of dentures. One frequent problem that occurs with denture bases is fracture. [14] It was reported that the most common problems for damage of removable dentures included breakage or fracture of the acrylic base (64%) and loosening of teeth. [15]

Although various methods have been proposed for repairing fractured denture base, the use of auto-polymerizing acrylic resin, which generally allows for a simple and quick repair, is the most popular. [16] However, dentures repaired with auto-polymerizing acrylic resin alone often experience a re-fracture at the repaired site. One of the reasons for this unfavorable phenomenon is the insufficient transverse strength of auto-polymerizing acrylic resin, which is lower than that of heat-polymerizing acrylic resin.(6) Therefore, various methods for enhancing the strength of the repaired part have been reported; these include combined use of auto-polymerizing acrylic resin with reinforcing materials, repair surface design, repair surface treatment, heat-cured acrylic resin and microwave energy. (17)

PMMA demonstrates poor strength characteristics. Hence, its low impact and flexural strength should be improved, it's use in the acrylic resin prosthesis different procedures have been considered in order to improve the impact properties of PMMA as development of an alternative material to PMMA; chemical modification of PMMA by creating transverse bands or by adding a rubber graft copolymer and reinforcement of PMMA with other materials such as carbon fibers, glass fibers, and ultra-high modulus polyethylene, tin, or aluminium nano-silver powder.(18, 19)

The transverse strength is described as a modulus of rupture or flexural strength. Measurement of the transverse strength is used in evaluation of denture plastics, as this strength closely resembles the type of loading applied to the denture in the mouth during mastication. (12,14)

Silver compounds have been historically used to control microbial proliferation. The antifungal and antibacterial effect of silver nano-particals AgNps, even against antibiotic-resistant bacteria has been demonstrated in in-vitro conditions. Nowadays, silver compounds are routinely applied in a wide array of industrial and sanitary fields, such as coating of catheters and surgery material, treatment of burn injuries, homeopathic medicine, water purification and textile fabrics and poses low toxicity to human cells, high thermal stability and low volatility. (20)

Silver nano-particles have been prepared by chemical reduction method as reported by Pal et al. (13) Silver nano-particles were prepared by microwave irradiation of silver nitrate ($AgN0_3$) solution in ethanol medium using PVP as a stabilizing agent. Ethanol was observed to act as reducing agent in the presence of microwave.

In a survey of denture repairs, auto- polymerized acrylic resin was the most preferred (86%) material for denture repair. Results from previous studies have shown that the strength of auto-polymerized resin repair is only 18 to 81% that of intact heat polymerized denture resin. Consequently, recurrent fractures are a very common phenomenon. (15, 21)

Incorporation of AgNps to cold cured acrylic resin have been considered in order to improve the flexure strength properties of cold cured acrylic resin, which is widely used in repairing fractured dentures.

Different designs for repairing (Bevel, Butt and Dovetail) were performed and different denture base materials (Microwave and Conventional acrylic resin denture base materials) were used for this study.

The results of this study indicated that incorporation of AgNp to cold cured acrylic resin recorded statistically significant higher flexure strength than cold cured cure in repaired samples with the different designs for repairing (Bevel, Butt and Dovetail) in both denture base materials (Microwave and Conventional acrylic resin denture base material), the null hypothesis was rejected .

This result is in agreement with previous studies. (20-22) that reported improvement of the compressive and impact strengths of the denture base by adding metal (aluminum and copper) droplets by 5 volume%. In the present study, adding 300 ppm (0.3mg / ml) of nano-silver powder (AgNPS) to PMMA improved its flexure strength. This increase in flexural strength could be attributed to nano-particle sizes, their distribution within the repair material along with the joint's surface design. The degree of the particles dispersion in the matrix is an important factor that influences the strength properties. It is evident that high surface area of the nanoparticles in PMMA/AgNPs, the applied stress is expected to be easily transformed from the matrix onto the AgNPs resulting in improvement of mechanical properties. Furthermore, the compatibility between the polymeric matrix and the nanoparticles is improved due to formation of more favorable polar interactions between C= O groups of the PMMA chains and AgNPs. [24,27]

On the other hand, this result came as disagreement with previous studies. The results of their study indicated that incorporation of AgNps significantly decreased the strength of PMMA. The explanation of this result might be attributed to less nano-silver particles per unit area of the PMMA matrix because of larger nano-silver particle size. It may also enhance the chances of void formation from entrapped air and moisture and incomplete wetting of the nano-particles by resin. Therefore, the net effect of embedding metal nano-particles was to weaken the polymer. [23,24] Similar reasons were cited by Sehjpal and Sod,[25] who reported that addition of silver, aluminum or copper powder to PMMA at a concentration of 25% by volume significantly decreased (by as much as 35%) the tensile strength of the acrylic resin polymer.

Incorporation of NP (nano-particles) causes these particles to agglomerate and aggregate. The agglomerated compounds can act as stress-concentrating centers in the matrix and adversely affect mechanical properties of the polymerized material. [23] In this study different concentrations were used and incorporation technique which may explain this disagreement with our result. In addition, varying PMMA solubility may explain the difference in results.

Also, the results of this study indicated that repairing the microwave denture base showed non-significant higher flexure strength than conventional heat cure acrylic resin denture base material, the null hypothesis was accepted. This result may be due to the temperature rises at the end of the curing cycle, and some free monomer is left in the resin with the conventional method. Microwaves act only on the monomer, which decreases in the same proportion as the polymerization degree increases. Therefore, the same amount of energy is absorbed by less and less monomer, making the molecules increasingly active. This is important because a form of self-regulation of the curing program takes place and leads to complete polymerization of the resin. [3]

In addition, the results of this study indicated that use a different design for repairing has non-significant difference between surface designs. Repair material and the repaired acrylic resin interface with the original material were another important factor that affected the overall repaired structure's mechanical properties. Moreover, the joint surface design has been proven to have a major impact on the strength of the repaired acrylic resin [12]

Cohesive failure primarily occurred with the bevel joint design, demonstrating that beveling of repair surface design increased the flexural strength. This strength increase might be due to the 45° beveling, which increased the interface surface area and consequently provided a wide bond area. Mechanically, the 45° beveling might also shift the damaged area's tensile stress to the shear stress at the interface of the repaired specimens. [26]

The limitations of this study included the fact that only one mechanical property was investigated (flexural strength) and only one type of nano-particle material was evaluated. For future research, other properties can be investigated and other nano-particle materials can also be used for reinforcement of the repair material. In addition, the mechanical tests were not accomplished within environments, similar to the conditions inside the oral cavity.

CONCLUSION

Within the limitations of this in- vitro study, the incorporation of nano- silver particles into a repair material, combined with repair surface design, improved the flexural strength of the repaired resin denture base.

REFERENCES

1. Alla RK, Sajjan S, Alluri VR, Ginjupalli K, Upadhya N. Influence of fibre reinforcement on the properties of denture base resins. J Biomater. Nanobiotech. 2013;4(1):91-7.
2. Kartika UK, Agrawal B, Yadav NS, Singh PP, Rahangdale T. The effect of microwave processing and use of antimicrobial agent on porosity of conventional heat cured denture base resin: An invitro study. J Indian Prosthodont Soc 2015;15:257-62
3. Somkuwar S, Mishra SK, Agrawal B, Choure R. Comparison of the flexural strength of polymethyl methacrylate resin reinforced with multiwalled carbon nanotubes and processed by conventional water bath technique and microwave polymerization. J Indian Prosthodont Soc 2017; 17:332-339
4. Alla RK, Swamy KNR, Ritu Vyas, Konakanchi A. Conventional & contemporary polymers used for fabrication of denture prosthesis: Part I – overview of composition, setting and properties. Int J App Dent Sci. 2015;1(4):82-89.
5. Seiko R, Hermana K, Neudenir J. Factors affecting the strength of denture repairs. J Prosthodont. 2007;16(4): 302-310
6. Alkurt M, Yeşil Duymuş Z, Gundogdu M. Effect of repair resin type and surface treatment on the repair strength of heat-polymerized denture base resin. J Prosthet Dent. 2014;111(1):71–78.
7. Faot F, da Silva WJ, da Rosa RS, et al. Strength of denture base resins repaired with auto- and visible light polymerized materials. J Prosthodont. 2009;18(6):496–502.
8. Minami H, Suzuki S, Minesaki Y, Kurashige H, Tanaka T. In vitro evaluation of the influence of repairing condition of denture base resin on the bonding of autopolymerizing resins. J Prosthet Dent. 2004;91(2):164–170.
9. Laura Susana Acosta-Torres, Irasema Mendieta, Rosa Elvira Nuñez-Anita, Marcos Cajero-Juárez, Víctor M. Castaño. Cytocompatible antifungal acrylic resin containing silver nanoparticles for dentures. International Journal of Nanomedicine. 2012;7:4777–4786.
10. Ghahremanloo A, Movahedzadeh M. The effect of silver nano particles on Candida albicans and Streptococcus mutans in Denture Acrylic Resins. J Dent Mater Tech 2016; 5(1):23-30.
11. Grzegorz Chladek, Anna Mertas, Izabela Barszczewska-Rybarek, Teresa Nalewajek, Jarosław Żmudzki, Wojciech Król, Jan Łukaszczyk. Antifungal activity of denture soft lining material modified by silver nanoparticles—a pilot study. Int. J. Mol. Sci. 2011;12:4735-4744.
12. Mohammed G, Rahoma A, al-Thobity M and Aws S. Influence of incorporation of ZrO2 nano-particle on the repair strength of polymethylmethacrylate denture bases. International Journal of Nano-medicine 2016; 11: 5633–5643.
13. Pal A, Shah , Devi S .Materials Chemistry and Physics 2009 (11); 4530- 532.
14. Patra N, Barone A. Salerno M, Caputo G, Cozzoli D and Athanassiou A. Thermal and mechanical characterization of PMMA TiO2 nano-composites. Adv. Mat. Res. 2009; 67: 209- 14.
15. Polyzois, G., Andereopoulos, A. and Lagouvardos, P: Acrylic resin denture repair with adhesive resin and metal wires; Effects on strength parameters. J. Prosthet. Dent. 1996 ; 75: 381- 387.
16. Abdulhamed A, Mohammed Ali M. Evaluation of thermal conductivity of alumina reinforced heat cure acrylic resin and some other properties. J Bagh College Dentistry 2010; 22: 1- 7
17. Bertassoni LE, Marshall GW, de Souza EM and Rached RN. Effect of pre- and post polymerization on flexural strength and elastic modulus of impregnated, fiber-reinforced denture base acrylic resins. J. Prosthet. Dent. 2008; 100 (6): 449– 57.
18. Bulbul M and Kesim B. The effect of primers on shear bond strength of acrylic resins to different types of metal. J. Prosthet. Dent. 2010; 103 (5): 303- 308.
19. Nakamura M, Takahashi H and Hayakawa I. Reinforcement of denture base resin with short-rod glass fiber. Dent Mater J. 2007; 26 (5): 733– 8.
20. Wadhera A and Fung M. Systemic argyria associated with ingestion of colloidal silver. Dermatology Online Journal 2005; 11, 12
21. Kostoulas I, Kavoura VT. Fracture force, deflection, and toughness of acrylic denture repairs involving glass fiber reinforcement. J Prosthodont. 2008;17(4):257–261.
22. John J, Gangadhar S and Shah I. Flexural strength of heat-polymerized polymethylmethacrylate denture resin reinforced with glass, aramid or nylon fibers. J. Prosthet. Dent. 2001; 86 (4): 424– 427.
23. Han Y, Kiat- amnuay S, Powers J and Zhao Y. Effect of nano-oxide concentration on the mechanical properties of a maxillofacial silicone elastomer. J. Prosthet. Dent. 2008; 100: 465– 73.

24. Alla RK, Swamy KNR, Ritu Vyas, Konakanchi A, Guduri V, Gadde P. Influence of Silver Nanoparticles Incorporation on Flexural Strength of Heat-cure Acrylic Denture Base Resin Materials. Annual Research & Review in Biology 2017;17(4): 1-
25. Sehajpal S, Sood V. Effect of metal fillers on some physical properties of acrylic resin. J prothet Dent 1989:61;746-57.
26. Hanna EA, Shah FK, Gebreel AA. Effect of joint surface contours on the transverse and impact strength of denture base resin repaired by various methods: an in vitro study. J Am Sci. 2010;6(9):115–125.
27. Kassaee MZ, Mohammadkhani M, Akhavan A, Mohammadi R. In situ formation of silver nanoparticles in PMMA via reduction of silver ions by mutilated hydroxytoluene. Struct Chem. 2011; 22: 11–5.