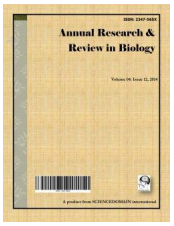

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Influence of Silver Nanoparticles Incorporation on Flexural Strength of Heat-cure Acrylic Denture Base Resin Materials

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Authors' contributions

This work was carried out in collaboration between all authors. Author RKA designed the study, wrote the protocol, managed the literature searches and wrote the first draft of the manuscript. Authors KNRS and RV guided and supervised the experimental process. Authors RKA, VG and AK made the test specimens and evaluated flexural strength. Author PG managed the statistical analyses. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To investigate the effects of silver nanoparticles on the flexural strength of three commercial heat-cure denture base materials such as Lucitone199, Trevlon, and TriplexHot.
Methodology: A total of 150 specimens were fabricated and assigned equally among the three selected denture base resin products. Samples in each denture base resin product were distributed

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among control, 0.5 wt%, 1.0 wt% 2.0 wt% and 5.0 wt% AgNPs added to the acrylic powder prior to the processing. Specimens without silver nanoparticles are considered as control group. Flexural strength was measured using three point bending method using universal testing machine at a crosshead speed of 2 mm per minute.

Results: One way ANOVA and Tukey HSD tests were used to analyse the results. Control group exhibited superior flexural strength whereas flexural strength of the specimens decreased with the increasing concentration of silver nanoparticles.

Conclusion: Incorporation of silver nanoparticles decrease the flexural strength of heat cure denture base materials and the flexural strength was influenced by the concentration of nanoparticles.

Keywords: Denture base materials; PMMA; silver nanoparticles; flexural strength.

1. INTRODUCTION

Poly methyl methacrylate (PMMA) resin was introduced in 1937 by "Walter Wright" [1,2]. Although, 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 [3-5], it has been the most widely used denture base material ever since it was introduced. The factors which influence the fracture of acrylic resin dentures include stress intensification and increased ridge re absorption, 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) [3,6-9]. Fracture of dentures by impact forces, on the other hand, is due to the accidental dropping of dentures [3,7,10,11]. To overcome the drawbacks of inferior mechanical properties and low thermal conductivity, conventional PMMA materials have been incorporated with metallic fillers with varying success. In addition, attempts have also been made to copolymerize PMMA with rubber materials to improve impact strength. Further, various fibers have been incorporated into PMMA to improve flexural, impact and fatigue strength. Though, these attempts were successful to certain extent, the problem of microbial adhesion remained as a critical feature of PMMA based denture base materials leading to Denture stomatitis [3,12-16].

Denture stomatitis is the most common consequence of prolonged denture wearing. The condition has not generally been considered serious, but does result in chronic inflammation and may act as a source for serious infection in the elderly or immune-compromised patients. The intaglio surface of the denture is not polished prior to insertion and these areas in denture may serve as breeding ground for opportunistic oral fungi [17,18]. Sahebjamee M, et al. [17] and Pachava KR, et al. [18] reported various treatments for Candida infection in denture stomatitis including removal of the source of irritation and applying antifungal agents orally in the form of drops, lozenges, or mouth washes. However, such attempts have largely been not successful due to the loss of the drug rapidly into the saliva, inhomogeneous distribution of the drug and development of resistance to antifungal therapy. Recently, numerous studies have reported the incorporation of silver nanoparticles (AgNPs) into conventional dental base materials that may act as good antifungal agents [19-24]. However, the effect of incorporation of AgNPs on mechanical properties of denture base materials has not been substantiated. Hence, this study aims to evaluate and compare the flexural strength and of heat cure denture base resin modified with the incorporation of different concentrations of AgNPs.

2. MATERIALS AND METHODS

Details of the materials used in the present study are presented in Table 1.

Table 1. Denture base materials used in the study

S. no.	Name of the materials	Manufacturer
1	Lucitone199	Dentsply International Inc, USA
2	Trevlon	Dentsply India Pvt. Ltd, India
3	TriplexHot	IvoclarVivadent, USA
4	Silver nanoparticles	Size 80-100nm, Nano Labs Pvt Ltd, India

2.1 Preparation of Acrylic Specimen

A total of 150 specimens were fabricated using conventional compression moulding technique. Acrylic specimens were fabricated by investing metal strips of 65 x 10 x 3 mm according to ADA specification number 12. Metal strips were carefully removed after the investment material was set. A thin layer of separating medium was applied in the mould space and allowed to dry. Denture base acrylic powder with or without silver nanoparticles and monomer liquid was mixed as per the manufacturer recommendations and packed into the mould when the mix reached the dough consistency. Then the flask was closed and a pressure of 4 lbs was applied and bench cured for 30 minutes in a hydraulic press apparatus (Silfradent, India). Then the flask was tightly secured in a clamp and transferred into a thermostatically controlled water bath (Acrylizer, Confident A-73, India) and cured as per the manufacturer's recommendations. Temperature of the water bath was increased to 73±1°C within 30 minutes and maintained at same temperature for 90 minutes. Then the temperature of the water bath was increased to 100°C and maintained for 60 minutes. After completion of polymerization cycle, the flask was allowed to cool in water bath to room temperature, and the acrylic resin specimens were retrieved after deflasking. The specimen obtained were finished and polished in the conventional manner [2].

2.2 Evaluation of Flexural Strength

The flexural strength was measured using a three point bending test on a computerized universal testing machine (Instron 8801, United Kingdom) at a cross-head speed of 2mm/minute. The load was applied until the specimen fractured from whom the flexural strength value was computed automatically by the machine. Results were subjected to One way ANOVA and TukeyHSD tests for statistical analyses using SPSS for windows, Version 12.0., SPSS Inc.

3. RESULTS

The means and standard deviations for flexural strength are displayed in Table 2. Control groups of all the tested materials showed more flexural strength than the modified groups of denture base materials. One-way ANOVA (Table 2) showed a significant difference (p = 0.000) in flexural among the three groups. PostHoc (Tukey's HSD) test (Table 3) showed significant differences (p = 0.000) between unmodified and modified groups except with the TriplexHot groups modified by 1.0 wt% and 2.0 wt% of AgNPs.

Among the modified groups, denture base materials modified with 0.5 wt% AgNPS showed highly significant differences (p = 0.000) with all modified Lucitone199 groups and TriplexHot groups except with the 5.0 wt% of AgNPs of TriplexHot. Statistically significant differences were also found among 1.0 wt% AgNPs groups of denture base materials and 2.0 wt% of Lucitone199 group, 2.0 wt% and 5.0 wt% of TriplexHot groups. Trevlon with 1.0 wt% and 2.0 wt%AgNPs showed insignificant differences with 0.5 wt% of modified materials and also between 2.0 wt% and 5.0 wt% of Trevlon groups. Irrespective of the weight percentage of AgNPs incorporated, Trevlon groups (both control and modified) showed more flexural strength among the tested groups (Fig. 1).

4. DISCUSSION

PMMA based resin is currently the most commonly used material for the construction of dentures. However, this material is not ideal because of its relatively low mechanical strength, which can cause the fracture of denture. This study was essentially designed to evaluate the mechanical properties of heat cure acrylic resins incorporated with different concentrations of AgNPs. Numerous researchers have studied the addition of AgNPs on the antifungal and antibacterial properties of denture base acrylic resins and denture lining materials [21,23-25]. They suggested that these nanoparticles serve as good antifungal and antibacterial agents in denture base materials and may be alternatives to the regularly used antibacterial and antifungal drugs. However, very limited literature is available on effect of these materials on physical and mechanical properties of denture base acrylic materials. Flexural strength is an important property for dental resins, as the major cause of prosthesis fracture in the oral cavity is related to stresses caused by repeated application of masticator forces they induce more bending movements [3,4,6,26].

Numerous researchers have reported about the improvement of denture base polymers by reinforcing various materials such as metal oxides, metal strengtheners, carbon/graphite fibers, aramid fiber, ultra-high molecular weight polyethylene fiber (UHMWPE), and glass fibers [3,13,27-31]. The size shape and distribution of filler particles in the polymer matrix, strong

Table 2. Comparison of flexural strength (MPa) of denture base materials modified with different concentrations of Ag nanoparticles using one-way ANOVA

Groups	N	Lucitone199		Trevlon		TriplexHot	
		Mean ± SD*	Significance	Mean ± SD*	Significance	Mean ± SD*	Significance
Control	30$	73.308 ± 2.699		108.623± 6.282		72.142± 2.619	
0.5 wt% AgNPs	30$	81.103 ± 9.061		87.212± 15.076		59.921± 1.692	
1.0 wt% AgNPs	30$	57.661 ± 2.720	0.000	86.690± 11.277	0.000	69.763± 3.916	0.000
2.0 wt%AgNPs	30$	66.230 ± 4.208		84.470± 0.629		70.092± 4.95	
5.0 wt% AgNPs	30$	62.226 ± 1.848		76.121± 6.680		63.562± 3.635	

**SD – Standard Deviation*

$ 10 specimens from each denture base material

Table 3. Post Hoc analysis (Tukey HSD) of flexural strength (MPa) of denture base materials modified with different concentrations of Ag nanoparticles

Groups		Lucitone199		Trevlon		TriplexHot	
		Mean difference ± SE	Significance	Mean difference ± SE	Significance	Mean difference ± SE	Significance
Control	0.5 wt% AgNPs	7.795 ± 2.172	0.007	21.411± 4.190	0.000	12.221± 1.584	0.000
	1.0 wt% AgNPs	15.647±2.172	0.000	21.933± 4.190	0.000	2.379± 1.584	0.567
	2.0 wt% AgNPs	7.078±2.172	0.017	24.153± 4.190	0.000	2.050± 1.584	0.696
	5.0 wt% AgNPs	11.082±2.172	0.000	32.502± 4.190	0.000	8.580± 1.584	0.000
0.5 wt% AgNPs	1.0 wt% AgNPs	23.442±2.172	0.000	0.522± 4.190	1.000	9.842± 1.584	0.000
	2.0 wt% AgNPs	14.873±2.172	0.000	2.742± 4.190	0.965	10.171± 1.584	0.000
	5.0 wt% AgNPs	18.877±2.172	0.000	11.091± 4.190	0.079	3.641± 1.584	0.165
1.0 wt% AgNPs	2.0 wt% AgNPs	8.569±2.172	0.002	2.220± 4.190	0.984	0.329± 1.584	1.000
	5.0 wt% AgNPs	4.565±2.172	0.237	10.569± 4.190	0.104	6.201± 1.584	0.003
2.0 wt% AgNPs	5.0 wt% AgNPs	4.004±2.172	0.362	8.349± 4.190	0.286	6.530± 1.584	0.001

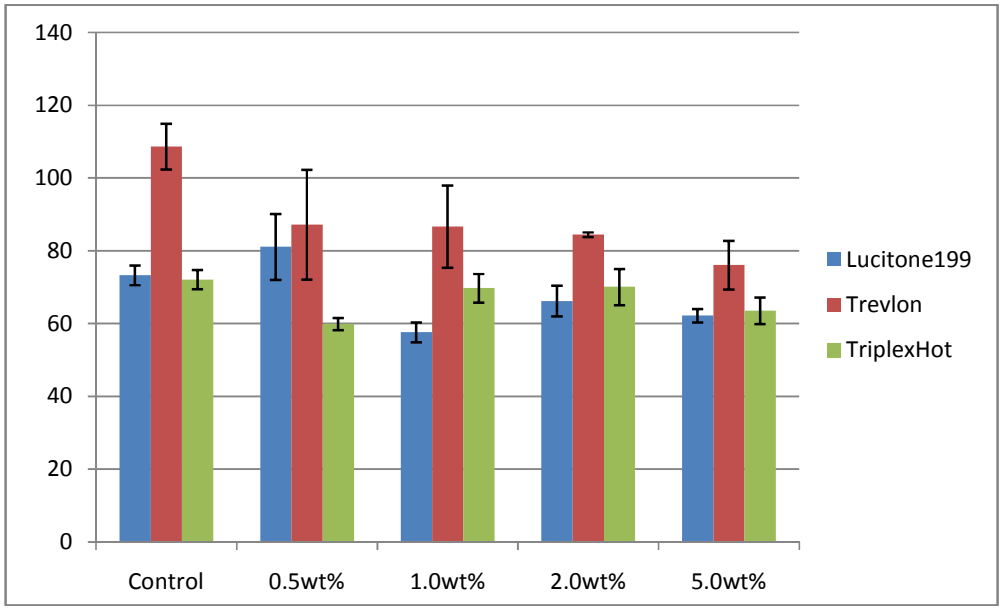

Fig. 1. Flexural strength (MPa) of denture base materials modified with AgNPs

adhesion at the interface and degree of cure play a major role on the mechanical properties of particulate filled polymer composites [31,32]. Korkmaz et al. [33] suggested that the size of filler particles should be small for proper processing. The average of particle size of PMMA beads used in commercially available denture base resins is around 100 µm [34]. The particle size of AgNPs (80-100 nm) used in this study is much smaller than that of powder resin particles. Thus, AgNPs will fill the interstitial of polymer particles to give a heterogenous mixture and will not force the displacement of the segments of polymer chain. In addition, low percentage of nanoparticles should be used to ensure that they will be embedded in resin.

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 an enhancement of the mechanical properties. Furthermore, the compatibility between the polymeric matrix and the nanoparticles is improved due to formation of more favourable polar interactions between C= O groups of the PMMA chains and AgNPs [35,36], possibly increasing the mechanical strength. Additionally, degree of cure (DC) is the other factor that affects the mechanical properties. Lower DC is usually associated with poorer mechanical properties [37]. More amount of unreacted monomer may act as plasticizer and decreases mechanical properties.

Results of this study suggest that addition of AgNPs alters flexural strength of PMMA depending on the amount of AgNPs employed. However, the flexural strength of all groups used in this study is more than the ISO 20795-1:2008 (ISO, 2008) requirement. According to ISO 20795-1:2008 (ISO, 2008), the flexural strength of polymeric materials must be at least 50 MPa. In our present study, all unmodified (control) specimens showed more flexural strength than the modified specimens except Luciton199 (Table 2, Fig. 1). Lucitone199 with 0.5wt% of AgNPs had demonstrated more strength than the control. At this concentration, Trevlon denture base materials also demonstrated more flexural strength than the other tested specimens. A gradual decrease in flexural strength was observed in modified Trevlon specimens from 0.5 wt% to 5.0 wt% AgNPs. It can be attributed to the degree of nanoparticles dispersion in the PMMA resin matrix and the chemical composition of the commercial acrylic resin material used in the study. From this study it can be believed that the polar interactions between the nanoparicles and C=O of polymer matrix (weak interactions) are adequate at low concentrations that results in improving the flexural strength. This is due to the fact that metal nanoparticles may bond with the

polymer molecules, crosslinking them between each other and, thereby, increasing the "pseudocrystallinity" of the polymer and forming an ordered system. However, increase in the concentration of nanoparticles in the polymer reduces the chemisorption interaction of the metal nanoparticle with the polymer, which leads to the disordered structure of the nanocomposite and reduces the mechanical strength [38]. At higher concentrations, nanoparticles may also act as impurities of polymerization that causes decrease in DC. Hence, more amount of unreacted monomer may be left over within the matrix that results in decreasing the flexural strength [39,40].

Sodagar et al. [40] investigated the influence of AgNPs on two self-cure rapid repair PMMA resin materials. They reported that the flexural strength depends on the concentration of filler within the resin matrix and composition of the commercial denture base resins. In our study, the groups with less concentration of AgNPs showed greater strength than the groups with more concentrations of AgNPs and each denture base material exhibited different flexural strengths. It is hence reported that the type of acrylic resin and the concentration of AgNPs incorporated are the important factors they affect the flexural strength. Similar to our study, Kassaee et al. [41] reported that incorporation of 0.5 wt% AgNPs increased flexural strength and antibacterial property. On contrary, WJ She [42], and Monterio et al. [21] suggested that these nanoparticles are effective antibacterial and antifungal agents for PMMA denture base acrylics but they found no significant effect on flexural strength [42].

Castro et al. [22] assessed the antimicrobial activity and the mechanical properties of an acrylic resin incorporated with nano Ag vanadate. They concluded that incorporation of these nanostructures can improve the antimicrobial activity in the acrylic resin. At lower concentrations, the mechanical properties were improved; however, at higher concentrations, no changes in the control were detected. This study supports our study as in low concentrations nanoparticles can improve the mechanical properties of denture base materials. Similarly, Korugulu A, et al. [43] demonstrated a slight decrease in the flexural strength of acrylic denture materials with increase in concentration of AgNPs, however, there was no statistical difference was found between the groups. This study indicates that the addition of AgNPs do not affect the flexural strength. In contrast to our findings, Abdulkareem MM et al. [44] demonstrated an increase in the flexural strength of microwave cured acrylic denture base material by increasing the concentration of silver nanofillers. Explicitly, it is evident that the chemical composition of acrylic resin, chemical interaction between nanoparticle and C=O group of PMMA polymer, filler particle size and DC will influence the flexural strength of PMMA based acrylic denture base materials. Dispersion of nanofillers in PMMA matrix is adversely affected by the degree of conversion which in turn leads to an increase in the level of residual unreacted monomer that acts as a plasticizer [45]. It is noteworthy that the content of nanoparticle additives is of critical importance.

5. CONCLUSION

From this study, it can be concluded that the incorporation of AgNPs decreases the flexural strength of denture base materials used in the study. Since these nanoparticles have good antibacterial and antifungal characteristics, at lower concentrations they may be incorporated into denture base materials. At higher concentrations, AgNPs impart black colour to the denture bases. Further studies are required to address the biocompatibility issues and optical properties of denture base materials modified with these nanoparticles.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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