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COMPARATIVE EVALUATION OF SILVER NANOPARTICLES AND TITANIUM DIOXIDE NANOPARTICLES ON FLEXURAL STRENGTH AFTER ITS INCORPORATION IN HEAT CURE ACRYLIC DENTURE BASE RESIN

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Background: The most commonly used denture base material is PMMA (polymethylmethacrylate). Denture fracture commonly results from impacting and flexural forces. To improve the antimicrobial properties of a denture base, various nanoparticles are being added including silver nanoparticles and titanium dioxide. However, literature data are scarce on nanoparticle's effect on flexural strength.

Aim: The present study aimed to comparatively assess the effect of adding silver nanoparticles and titanium dioxide nanoparticles on flexural strength after its incorporation in heat cure acrylic denture base resin.

Methods: 260 specimens were divided into 4 groups where Group I, II, III, and IV were reinforced with a mixture of silver nanoparticles and titanium oxide, silver nanoparticles, titanium oxide (TiO_2), and control respectively. 4 groups were subdivided based on concentration to 0.5%, 1%, 2%, and 3%. Mold space for specimen fabrication was used to form a mold space. After distilling water immersion for 2 weeks, flexural strength was determined using a three-point bend test. The data gathered were statistically analyzed and results were formed.

Results: A statistically significant gradual decrease was seen with the increase in the nanoparticles concentration on comparing the mean flexural strength. Minimum flexural strength was seen with combined silver and titanium oxide nanoparticles, whereas, maximum flexural strength was seen in the control group. No color change was seen with the modified specimen.

Conclusion: The study concludes that adding silver and titanium oxide particles in an in-vitro environment decreases the flexural strength of the polymethyl methacrylate.

Keywords: Denture base acrylic resin, flexural strength, silver, titanium dioxide, silver

INTRODUCTION

Life expectancy has increased with advances in the medical field with an increase in the number of geriatric subjects, which, in turn, increase the need for removable prosthesis. Generally, PMMA (polymethylmethacrylate) has been used as a material for denture bases in the fabrication of various prostheses including implant-supported dentures, oral and maxillofacial prostheses, and dentures. PMMA meets all the needs of an ideal base material for the denture base including the low-cost equipment need, excellent esthetics, color stability, fir, stability, and a favorable working environment. It is used widely owing to its esthetics, mechanical properties, long-term reliability, and host-tissue biocompatibility.[1]

With passing years, different materials have been added to improve the antimicrobial property of PMMA including tulsi extract, aloe vera extract, silver nitrate, and/or nystatin. Also, including titanium dioxide and silver particles in PMMA recently has shown better antibacterial and antifungal properties. Impact and flexural fatigue have been predominantly considered a cause of denture fracture. Flexural fatigue results following reduplicated flexing of material, whereas, minor cyclic loads on any structure may lead to material fracture. Impact fractures arise extra orally from accidental drops or sudden jolts during sneezing, coughing, or brushing.[2]

Various attempts have been made to improve the mechanical properties of acrylic materials. However, most of these attempts are not well accepted in clinical dentistry owing to high cost and processing straits. Literature studies have reported improvement in physical properties with the addition of prepolymer, silica, titanium dioxide, silver nanoparticles, silica nanoparticles, zinc oxide, and e-glass fibers.[3]

The addition of nanoparticles to PMMA improves its antimicrobial properties along with improvement in esthetic properties and ductility, better strength, and modulus. Titanium dioxide nanoparticles are non-toxic, biologically compatible, result in improved mechanical and antimicrobial properties, and inexpensive are and widely acceptable. Titanium dioxide also acts against various viruses, fungi, and bacteria.[4]

One of the other commonly used nanoparticles is silver as they have antimicrobial properties, thermal conductivity, electrical conductivity, and ductility. Adding silver particles in PMMA can decrease the esthetic value by discoloration and reduce tensile strength with an increase in compressive strength. No conclusive literature data exist depicting the effect of silver addition on the flexural strength of PMMA.[5]

Hence, the present study aimed to comparatively assess the effect of adding silver nanoparticles and titanium dioxide nanoparticles on flexural strength after its incorporation in heat cure acrylic denture base resin.

The study also assessed the flexural strength of the study specimen and a comparison was done with the control group.

MATERIAL AND METHODS

The present in vitro study was done at department of Prosthodontics. For the study, the dimension of samples was made based on ADA specification No. 12 using 65mm X 10 mm X 3 mm for assessing the flexural strength. Specimens having irregular surfaces, visible surface porosities, and lesser dimensions were not used.

Five block models of stainless steel were made in larger dimensions to compensate for the polymerization shrinkage, finishing, and trimming while acrylic resin replacement is done. Modeling wax extension was further made for easy retrieval without edge damage from the dental stone. The flasks were then placed in the dewaxing chamber for 30 minutes.[6] This mold was utilized to make acrylic specimens incorporated with the nanoparticles.

In the control group (IV), to prepare specimens, polymer, and monomer were mixed following the manufacturer's recommendations and were packed in the flask when were then heat cured for 2 hours at 74^oC and the water bath temperature was increased to 100^oC for 1 hour and bench curing for 30 minutes. This was followed by immersion in cool tap water for 15 minutes. After curing, resin blocks were removed, trimmed, and finished using a lathe and sandpaper. The dimensions were then verified to the measurement specified. The samples were then placed in distilled water to remove residual polymer and monomer followed by testing.

Using a high-precision digital balance, commercially available silver and titanium dioxide nanoparticles were weighed and added to the test tube having MMA (methyl methacrylate) monomer. A sonicator was then used for sonicating to get a homogenous suspension. Based on the various concentrations of nanoparticles, the test tubes were labeled (0.5%, 1%, 2%, and 3%). A similar process was repeated for specimens having a mixture of titanium dioxide and silver nanoparticles and having silver nanoparticles alone. The mixture for each sample was packed and processed identically.

Before testing for flexural strength, specimens were placed in distilled water at room temperature for 50 hours followed by a fracture in a universal testing machine. Three-point bend test was done maintaining cross-head speed at 5mm/min. The maximum force (F) needed to fracture the specimen was recorded in N (newton) and flexural strength was recorded in MPa for all samples following: $Q=3FI/(2BH^2)$ where I depict the distance in two supporting points (mm), B was for specimen width (mm), and H was the height of specimen subjected to bending (mm).

Flexural strength was compared between the control group (IV) having conventional permanent acrylic denture base resin to Group I with titanium dioxide nanoparticles and silver nanoparticles incorporated permanent acrylic denture base material (subgroups 0.5%, 1%, 2%, and 3% by weight), Group II silver nanoparticle incorporated permanent acrylic denture base material (subgroups 0.5%, 1%, 2%, and 3% by weight), and Group

III titanium dioxide nanoparticle incorporated heat-polymerizing denture base material (subgroups 0.5%, 1%, 2%, and 3% by weight). The data gathered were analyzed statistically using post hoc Turkey's test and ANOVA (analysis of variance). The level of significance was kept at $p<0.05$.

RESULTS

The present study aimed to comparatively assess the effect of adding silver nanoparticles and titanium dioxide nanoparticles on flexural strength after its incorporation in heat cure acrylic denture base resin. The study results showed that for comparison of the flexural strength between different study groups at the same concentration and controls, it was seen that at a concentration of 0.5%, mean maximum flexural strength was seen for control group IV with 138.54±4.82 followed by 125.03±6.05 MPa for TiO_2, 115.84±4.24 MPa for silver, and least 105.62±4.07 MPa for combined TiO_2 and silver. This difference was statistically significant with p=0.0001. At 1% concentration, similar results were seen where maximum flexural strength was seen for control group IV followed by TiO_2, silver, and least for combined TiO_2 and silver. These results were statistically significant with p=0.0001. Similar significant results were seen at concentrations of 2% and 3% with p=0.0001 as shown in Table 1.

On comparing the flexural strength between different study groups at different concentrations of titanium dioxide and controls. The highest mean flexural strength was seen for controls with 138.58±4.82 MPa followed by 0.5%, 1%, 2%, and 3% TiO_2 concentration with a mean flexural strength of 125.04±6.05, 118.25±4.99, 106.77±4.88, and 94.99±5.36 MPa respectively. The difference was statistically significant with p=0.0001 as depicted in Table 2.

Concerning the flexural strength between different study groups at different concentrations of silver nanoparticles and controls. The highest mean flexural strength was seen for controls with 138.57±4.82 MPa followed by 0.5%, 1%, 2%, and 3% silver concentration with a mean flexural strength of 115.87±4.24, 106.36±4.05, 95.42±3.27, and 87.07±2.45 MPa respectively. The difference was statistically significant with p=0.0001 as shown in Table 3.

In evaluating the flexural strength between different study groups at different concentrations of silver nanoparticles and titanium dioxide nanoparticles to controls, the results are summarized in Table 4. The highest mean flexural strength was seen for controls with 138.57±4.82 MPa followed by 0.5%, 1%, 2%, and 3% concentrations of combined silver and titanium dioxide nanoparticles with respective mean flexural strengths of 105.66±4.06, 94.39±2.82, 83.52±2.88, and 75.57±3.20 MPa. The difference was statistically significant with p=0.0001.

DISCUSSION

The present in-vitro study was aimed to comparatively assess the effect of adding silver nanoparticles and titanium dioxide nanoparticles on flexural strength after its incorporation in heat cure acrylic denture base resin. The study results showed that for comparison of the flexural strength between different study groups at the same concentration and controls, it was seen that at a concentration of 0.5%, mean maximum flexural strength was seen for control group IV with 138.54±4.82 followed by 125.03±6.05 MPa for TiO_2, 115.84±4.24 MPa for silver, and least 105.62±4.07 MPa for combined TiO_2 and silver. This difference was statistically significant with p=0.0001. At 1% concentration, similar results were seen where maximum flexural strength was seen for control group IV followed by TiO_2, silver, and least for combined TiO_2 and silver. These results were statistically significant with p=0.0001. Similar significant results were seen at concentrations of 2% and 3% with p=0.0001. These results were in line with the results of Besinis A et al[7] in 2014 and Ahmed MA et al[8] in 2016 where authors reported higher flexural strength for silver nanoparticles compared to titanium dioxide.

It was also seen that the flexural strength between different study groups at different concentrations of titanium dioxide and controls. The highest mean flexural strength was seen for controls with 138.58±4.82 MPa followed by 0.5%, 1%, 2%, and 3% TiO_2 concentration with a mean flexural strength of 125.04±6.05, 118.25±4.99, 106.77±4.88, and 94.99±5.36 MPa respectively. The difference was statistically significant with p=0.0001. These results were consistent with the previous studies of Rahul T[9] in 2020 and Sanjiv RD et al[10] in 2022 where authors reported similar results for flexural strength with titanium oxide-reinforced PMMA.

The results of the present study concerning the flexural strength between different study groups at different concentrations of silver nanoparticles and controls. The highest mean flexural strength was seen for controls with 138.57±4.82 MPa followed by 0.5%, 1%, 2%, and 3% silver concentration with a mean flexural strength of 115.87±4.24, 106.36±4.05, 95.42±3.27, and 87.07±2.45 MPa respectively. The difference was statistically significant with p=0.0001. These results were in agreement with the findings of Noronha VT et al[11] in 2017 and Ghaffari T et al[12] in 2014 where authors suggested similar effects of silver nanoparticle reinforcement on PMMA acrylic denture base resin.

On assessing the flexural strength between different study groups at different concentrations of silver nanoparticles and titanium dioxide nanoparticles to controls, the highest mean flexural strength was seen for controls with 138.57±4.82 MPa followed by 0.5%, 1%, 2%, and 3% concentrations of combined silver and titanium dioxide nanoparticles with respective mean flexural strengths of 105.66±4.06, 94.39±2.82, 83.52±2.88, and 75.57±3.20 MPa. The difference was statistically significant with p=0.0001. These results were comparable to the studies of Colvenkar SS et al[13] in 2022 and Somani MV et al[14] in 2019 where authors suggested high flexural strength for PMMA with no nanoparticle reinforcement.

CONCLUSION

Considering its limitations, the present study concludes that adding silver and titanium oxide particles in an in-vitro environment decreases the flexural strength of the polymethylmethacrylate, and the highest flexural strength is seen with PMMA with no nanoparticle reinforcement. However, the study has a limitation of being in-vitro nature. Hence, further clinical studies are needed in-vivo environment to reach a definitive conclusion.

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TABLES

Group	Number (n)	Mean± S. D	p-value
I (TiO2 + Ag) 0.5%	20	105.62±4.07	0.0001
II (Ag) 0.5%	20	115.84±4.24	
III (TiO_2) 0.5%	20	125.03±6.05	
IV (Control) 0.5%	20	138.54±4.82	
Total	80	121.25±13.11	
I (TiO2 + Ag) 1%	20	94.36±2.83	0.0001
II (Ag) 1%	20	106.36±4.08	
III (TiO_2) 1%	20	118.21±5.03	
Total	80	114.37±7.00	
I (TiO2 + Ag) 2%	20	83.48±2.88	0.0001
II (Ag) 2%	20	95.38±3.28	
III (TiO_2) 2%	20	106.73±4.87	
Total	80	106.03±21.11	
I (TiO2 + Ag) 3%	20	75.54±3.21	0.0001
II (Ag) 3%	20	87.12±2.42	
III (TiO_2) 3%	20	94.95±5.36	
Total	80	99.03±24.44	

Table 1: Flexural strength comparison between different study groups at the same concentration and controls

Group	Number (n)	Mean± S. D	p-value
0.5% TiO2	20	125.04±6.05	0.0001
1% TiO2	20	118.25±4.99	
2% TiO2	20	106.77±4.88	
3% TiO2	20	94.99±5.36	
Control	20	138.58±4.82	
Total	100	116.73±15.92	

Table 2: Flexural strength comparison between different study groups at different concentrations of titanium dioxide and controls

Group	Number (n)	Mean± S. D	p-value
0.5% Ag	20	115.87±4.24	0.0001
1% Ag	20	106.36±4.05	
2% Ag	20	95.42±3.27	
3% Ag	20	87.07±2.45	
Control	20	138.57±4.82	
Total	100	108.67±18.38	

Table 3: Flexural strength comparison between different study groups at different concentrations of silver and controls

Group	Number (n)	Mean± S. D	p-value
0.5% TiO2+Ag	20	105.66±4.06	**0.0001**
1% TiO2+Ag	20	94.39±2.82	
2% TiO2+Ag	20	83.52±2.88	
3% TiO2+Ag	20	75.57±3.20	
Control	20	138.57±4.82	
Total	100	99.54±22.47	

Table 4: Flexural strength comparison between different study groups at different concentrations of titanium dioxide with silver nanoparticles and controls