DOI: 10.22270/jmpas.V11I1.2171 ISSN NO. 2320–7418

International peer reviewed open access journal

Journal of Medical Pharmaceutical and Allied Sciences

Journal homepage: www.jmpas.com CODEN: JMPACO

Research article

Evaluation of flexural strength and surface hardness of heat activated provisional PMMA resin reinforced with nanoparticles-an in vitro study

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ABSTRACT

The provisional restorations are subjected to vertical, lateral and horizontal forces during function, hence the mechanical properties of the provisional materials to be taken into account before choosing for clinical use. The objectives of the study were to evaluate and compare the flexural strength and surface hardness of heat polymerized provisional polymethylmethacrylate resin reinforced with 2.5% Zirconia, Titanium or Aluminum oxide nano-particles. According to ISO 10477:2018, die was made in 25 mm x 2 mm x 2mm for flexural strength and wheel die in 15 mm diameter and 1mm thickness for hardness test. A total of 160 samples were fabricated and divided into Groups. I- (samples kept in distilled water for 24 hours after fabrication) and Group. II (samples kept in artificial saliva for 2 weeks after fabrication) and subdivided into Group-a(control), samples reinforced with 2.5% Zirconia nanoparticle (Group b), samples reinforced with 2.5%Titanium oxide nanoparticles (Group c), samples reinforced with 2.5% Aluminum oxide nanoparticles (Group d). The flexural strength was evaluated by three-point bending test and the hardness was evaluated using digital Vickers micro hardness tester. The values were statistically analyzed using one way ANOVA and Tukey's HSD test at significant level $P<0.05$. The flexural strength and surface hardness of 2.5% Zirconia and Titania nanoparticles reinforced heat polymerized provisional PMMA resin showed higher values than 2.5% Aluminum oxide nanoparticles group. The heat polymerized provisional PMMA resin reinforced with 2.5% nanoparticles of Zirconia and Titania showed statistically significant flexural strength and surface hardness compared to conventional heat polymerized provisional PMMA resin.

Keywords: Flexural strength, Heat activated PMMA resin, Provisional restoration, Surface hardness.

Received - 13-10-2021, Accepted - 19-01-2022

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INTRODUCTION

Absence of teeth is the most common problem for every human being. Tooth replacement can be done by removable dental or fixed dental prosthesis. Removable prosthesis restores chewing efficiency and fixed prosthesis not only restores chewing efficiency but also maintains esthetics and psychological satisfaction of patients [1][2]. Temporary prosthetic treatment is a fixed or removable prosthesis, given temporarily for esthetical reason, stabilization, and function which later need to be replaced with a permanent prosthesis [3].

The functions of provisional restorations are biological and esthetically acceptable [4]. They are subjected to masticatory forces and muscle forces during function. To withstand all occlusal forces, the mechanical properties of the provisional materials to be considered before selecting a temporary crown and bridge material for clinical use [5]. In clinical conditions like full mouth rehabilitation with reduced vertical dimension, long-span bridges, temporomandibular joint disorders, parafunctional habits, the mechanical properties of provisional restoration should be strong enough for such specific clinical conditions [6]. In addition, patients under dental implants therapy need a healing period of three or more months. Some cases, implant placement combined with additional procedures like bone or soft tissue augmentation need temporary long span bridges which should be used for period ranging from few months to a year over the implant sites [7].

The polymethylmethacrylate resin is a commonly used provisional restorative material and the major drawback of acrylic material is low flexural strength and surface hardness, therefore, by reinforcing with other materials to the PMMA resin may strengthen the acrylic material [8].

Nanoparticles are solid tiny particles of size ranging from 1 to 100 nm, have been added in dental materials to improve its mechanical properties. Reinforcing acrylic resins with different metal oxides, nanoparticles has been attempted, like Zinc, Titanium and Aluminum. Zirconium oxide (zirconia) nanoparticle have been reported in many studies. Various studies, proved that the different concentrations of nanoparticles which affected the mechanical and physical properties of PMMA, and not by incorporating of different sizes of nanoparticle [9]. There is no research on the combination of Zirconia, Titanium and Aluminum oxide nanoparticles on flexural strength and surface hardness. Hence this study was done to evaluate and compare the flexural strengths and surface hardness of heat polymerized provisional PMMA resin reinforced with 2.5% Zirconia, Titanium oxide and Aluminum oxide nanoparticles after 24 hours in distilled water and 2 weeks in artificial saliva after fabrication. A hypothesis was formulated that the flexural strength and surface hardness of the nanoparticles reinforced heat polymerized provisional PMMA resin will be the same as conventional heat polymerized provisional PMMA resin.

MATERIAL AND METHOD

According to International Organization for Standardization (ISO) 10477:2018 a master split die was fabricated with a dimension of 25mm x 2mm x 2mm, (Figure 1) for flexural strength test and a wheel shape die was fabricated with the dimension of 15 mm diameter and 1mm thickness for micro-Vickers hardness test. (Figure 2).

Figure 1: Schematic representation of die for flexural strength

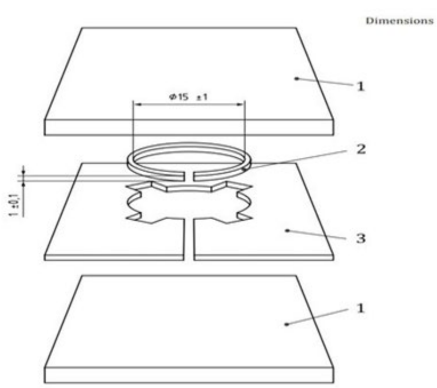
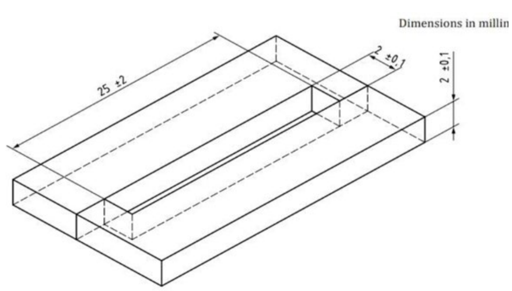


Figure 2: Schematic representation of die for surface hardness



Fabrication of control samples

The wax pattern was made over the metallic die using modelling wax (Modelling wax no.2- HDP, Hyderabad, India), then the wax patterns were invested in dental flask through 2 pour techniques with dental plaster (RSCM, Chennai, India). After the investing materials had set, the flasks were placed for dewaxing in hot water bath at 90^{O} C for 4-6 minutes. Following the dewaxing procedure, the separating medium (cold mold seal-DPI, Mumbai, India) was applied and allowed to dry. The provisional tooth color resin polymer and monomer (DPI, Mumbai, India) were mixed in the ratio of 3: 1 and then packed into mold space at room temperature and was kept in a hydraulic press (Silfradent, Chennai, India) at 200 bars pressure for 5 min, and then the flask is kept to set and polymerize for 30 min. Then polymerization was done in controlled temperature water bath (Delta curing unit, India) and processed by heating it to 74°C for 2 hours and then 100°C for 1-hour min. The flask was slowly cooled to room temperature for 30 min bench cooled, the provisional resin samples were retrieved, the finishing of the samples was done using 400 and 600 grit silicon carbide grinding paper (TORA, India). All the samples were examined using a digital caliper to get 0.01 mm accuracy and proper dimensions.

Fabrication of experimental samples

Zirconia nanoparticle powder of 30-50 nm (Ultra nanotech, Bangalore, India) was weighed and incorporated about 2.5gms into 97.5gms of polymer powder then mixed using a ball milling machine. Similarly, 2.5% weight of Titanium oxide and Aluminum oxide nanoparticles of 30-50 nm (Ultra nanotech, Bangalore, India) were mixed in the ratio of 3:1 then packed into mold space at room temperature and kept in a hydraulic press (Silfradent, Chennai, India) at 200 bars pressure for 5 min, and then the flask is kept to set and polymerize for 30 min. Then polymerization was done in controlled temperature water bath (Delta curing unit, India) and processed by heating it to 74°C for 2 hours and then to 100°C for 1 hour. The flask was slowly cooled to room temperature for 30 min then bench cooled, the acrylic samples were retrieved, the finishing of the samples was done using 400 and 600 grit silicon carbide grinding paper (TORA, India). All the samples were examined using a digital caliper to get 0.01 mm accuracy and proper dimensions.

Distribution of samples

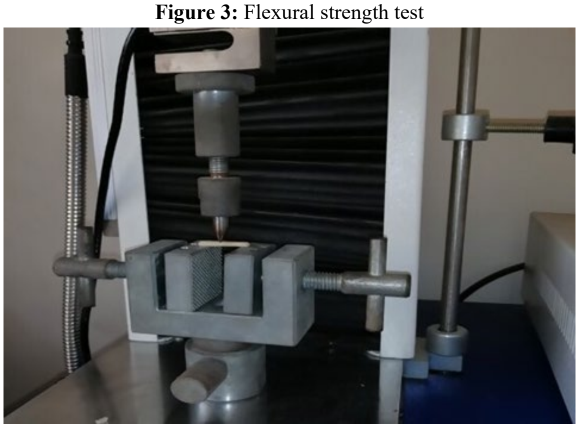
The flexural strength evaluation samples were considered as Group F and for evaluation of surface hardness were considered as Group S. Group F (flexural strength), were categorized into two; samples kept in distilled water for 24 hours after fabrication (Groups I) and samples kept in artificial saliva for 2 weeks after fabrication (Group II). Again, the samples were subdivided into four, samples without any nanoparticles were considered Group- a (control), samples mixed with 2.5% Zirconia nanoparticle (Group -b), samples mixed with 2.5% Titanium nanoparticles (Group-c), samples mixed with 2.5 % Aluminum oxide nanoparticles (Group-d). All the samples were examined under Scanning Electron Microscope (SEM) for distribution of nanoparticles in the sample. (Phenom Pro X, Phenom-World B V, Netherland)

Evaluation of flexural strength and surface hardness

The flexural strength of the samples was evaluated by a 3-point bend test [10] by an UTM 5 mm speed/minute (Instron 3367, Instron Corp, Canton, MA, USA). The flexural strength is calculated by the formula $S=3FL/2bd^2$, where F is exerting force at the center of sample, L is distance joining the two supports of the jaw; b and d are width and thickness of the sample, respectively. (Figure 3)

The surface hardness was evaluated using Digital Vickers hardness tester in which a 50 grams load was applied on surface of sample (Model MDV 401, Wilson Wolpert, Germany) and an indentation is made on surface of sample using diamond indenter for 10 sec and the surface micro hardness was calculated using Vickers hardness test [11] $VHN = 1.854 L d^2$ where: VHN: Vickers hardness in Kg/mm2, L: Load in Kg. d: Length of the diagonals in mm.

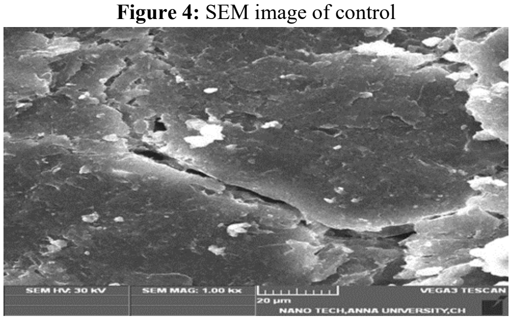
Figure 3: Flexural strength test



SEM analysis

The samples were evaluated under Scanning Electron Microscope (TESCAN VEGA 3) for distribution of nanoparticle in PMMA resin. The SEM images of conventional heat polymerized PMMA provisional resin showed surfaces with micro cracks and densely packed resin matrix with less space for crack to propagate.(Figure 4).

Figure 4: SEM image of control



The SEM image of 2.5% Zirconia nanoparticles reinforced heat polymerized PMMA provisional resin showed reduced number of micro cracks which is evidence of an increase in flexural strength and hardness of PMMA resin matrix.(Figure 5) The SEM image of 2.5% Titanium oxide nanoparticles reinforced heat polymerized PMMA provisional resin showed uneven distribution of untreated Titanium nanoparticles in heat polymerized resin matrix (Figure 6) and 2.5% Aluminum nanoparticles reinforced heat polymerized PMMA provisional resin showed spaces in resin matrix denoting 2.5% inadequate percent for reinforcement of PMMA resin. (Figure 7)

Figure 5: SEM image of provisional PMMA reinforced with 2.5% Zirconia nanoparticles

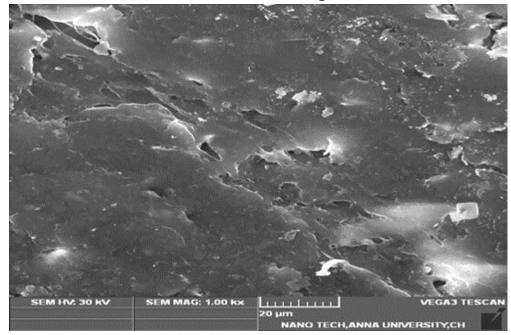


Figure 6: SEM image of provisional PMMA reinforced with 2.5% Titania nanoparticles

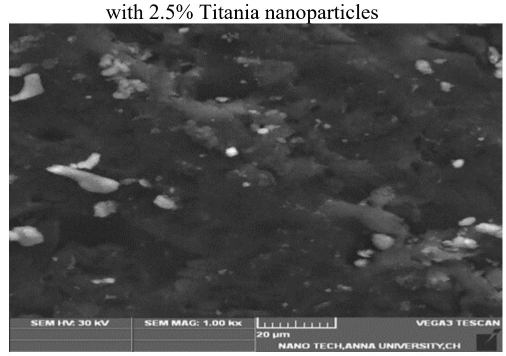
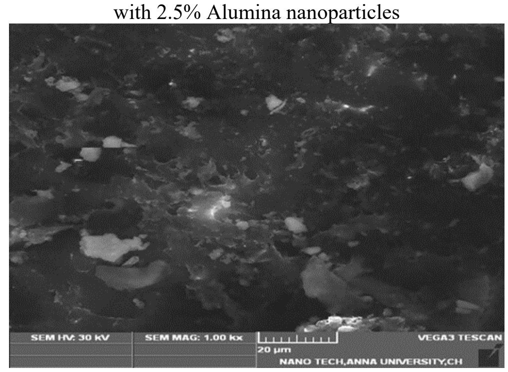


Figure 7: SEM image of provisional PMMA reinforced with 2.5% Alumina nanoparticles



Statistical analysis

The values obtained in this study were analyzed using the software SPSS for Windows V17 (Chicago, USA). The flexural strength and surface hardness values were statistically analyzed using two-way ANOVA for comparison within the group and Tukey's HSD Test for multiple group comparison. The results were considered as significant if the P value was < 0.05.

RESULTS

The mean and standard deviation of flexural strength of samples are given in Table 1.

The comparison of flexural strength of heat polymerizing PMMA provisional resin in distilled water for 24 hours and 2 weeks in artificial saliva after fabrication within the groups were done using two way analysis of variance (ANOVA).The results of the study showed the significance values were $P < 0.05$, hence it is considered as statistically significant.(Table 2) Multiple group comparison of flexural strength of heat polymerizing PMMA provisional resin in distilled water for 24 hoursand 2 weeks in artificial saliva after fabrication showed the significance values were $p < 0.05$. Hence it is considered as statistically significant for other groups. (Table 3)

The mean and standard deviation of surface hardness of samples are given in Table 4.The comparison of surface hardness of heat polymerizing PMMA provisional resin in distilled water for 24 hours and 2 weeks in artificial saliva after fabrication within the groups showed the significance values were $P < 0.05$, hence it is considered as statistically significant.(Table 5) Multiple group comparison of surface hardness of heat polymerizing PMMA provisional resin in distilled water for 24 hoursand 2 weeks in artificial saliva after fabrication showed that the significance values were $p < 0.05$, to control and 2.5% Zirconia and 2.5% Titanium oxide and 2.5% Zirconia nanoparticles comparisons. Hence the other group comparisons were statistically insignificant. (Table 6)

Table 1: Basic data of flexural strength

	Group	Mean	Std. Deviation	N
F S Heat Cure Artificial Saliva	Control group	178.1850	4.94557	10
	Zirconia group	196.2968	6.81415	10
	Titanium group	193.4920	5.27921	10
	Aluminum group	187.8978	5.47817	10
	Total	**188.9679**	**8.87940**	**40**
F S Heat Cure Distilled Water	Control group	176.1170	10.04333	10
	Zirconia group	195.9610	8.43316	10
	Titanium group	189.3432	5.96813	10
	Aluminum group	189.6553	4.15307	10
	Total	**187.7691**	**10.26922**	**40**

Table 2: Two-way analysis of variance (ANOVA) for flexural strength of heat polymerized PMMA provisional resin in distilled water for 24 hours and two weeks in artificial saliva after fabrication

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
F S Heat Cure Artificial Saliva	Control	Zirconia	-18.1118*	2.53744	.000	-24.9457	-11.2779
		Titanium	-15.3070*	2.53744	.000	-22.1409	-8.4731
		Aluminum	-9.7128*	2.53744	.003	-16.5467	-2.8789
	Zirconia	Control	18.1118*	2.53744	.000	11.2779	24.9457
		Titanium	2.8048	2.53744	.689	-4.0291	9.6387
		Aluminum	8.3990*	2.53744	.011	1.5651	15.2329
	Titanium	Control	15.3070*	2.53744	.000	8.4731	22.1409
		Zirconia	-2.8048	2.53744	.689	-9.6387	4.0291
		Aluminum	5.5942	2.53744	.141	-1.2397	12.4281
	Aluminum	Control	9.7128*	2.53744	.003	2.8789	16.5467
		Zirconia	-8.3990*	2.53744	.011	-15.2329	-1.5651
		Titanium	-5.5942	2.53744	.141	-12.4281	1.2397
F S Heat Cure Distilled Water	Control	Zirconia	-19.8440*	3.35301	.000	-28.8744	-10.8136
		Titanium	-13.2262*	3.35301	.002	-22.2567	-4.1958
		Aluminum	-13.5383*	3.35301	.001	-22.5687	-4.5078
	Zirconia	Control	19.8440*	3.35301	.000	10.8136	28.8744
		Titanium	6.6178	3.35301	.217	-2.4127	15.6482
		Aluminum	6.3057	3.35301	.254	-2.7247	15.3362
	Titanium	Control	13.2262*	3.35301	.002	4.1958	22.2567
		Zirconia	-6.6178	3.35301	.217	-15.6482	2.4127
		Aluminum	-.3120	3.35301	1.000	-9.3424	8.7184
	Aluminum	Control	13.5383*	3.35301	.001	4.5078	22.5687
		Zirconia	-6.3057	3.35301	.254	-15.3362	2.7247
		Titanium	.3120	3.35301	1.000	-8.7184	9.3424

Table 3: Tukey´s Post Hoc Test for flexural strength of heat polymerized PMMA provisional resin in distilled water for 24 hours and two weeks in artificial saliva after fabrication

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
F S Heat Cure Artificial Saliva	Control	Zirconia	-18.1118*	2.53744	.000	-24.9457	-11.2779
		Titanium	-15.3070*	2.53744	.000	-22.1409	-8.4731
		Aluminum	-9.7128*	2.53744	.003	-16.5467	-2.8789
	Zirconia	Control	18.1118*	2.53744	.000	11.2779	24.9457
		Titanium	2.8048	2.53744	.689	-4.0291	9.6387
		Aluminum	8.3990*	2.53744	.011	1.5651	15.2329
	Titanium	Control	15.3070*	2.53744	.000	8.4731	22.1409
		Zirconia	-2.8048	2.53744	.689	-9.6387	4.0291
		Aluminum	5.5942	2.53744	.141	-1.2397	12.4281
	Aluminum	Control	9.7128*	2.53744	.003	2.8789	16.5467
		Zirconia	-8.3990*	2.53744	.011	-15.2329	-1.5651
		Titanium	-5.5942	2.53744	.141	-12.4281	1.2397
F S Heat Cure Distilled Water	Control	Zirconia	-19.8440*	3.35301	.000	-28.8744	-10.8136
		Titanium	-13.2262*	3.35301	.002	-22.2567	-4.1958
		Aluminum	-13.5383*	3.35301	.001	-22.5687	-4.5078
	Zirconia	Control	19.8440*	3.35301	.000	10.8136	28.8744
		Titanium	6.6178	3.35301	.217	-2.4127	15.6482
		Aluminum	6.3057	3.35301	.254	-2.7247	15.3362
	Titanium	Control	13.2262*	3.35301	.002	4.1958	22.2567
		Zirconia	-6.6178	3.35301	.217	-15.6482	2.4127
		Aluminum	-.3120	3.35301	1.000	-9.3424	8.7184
	Aluminum	Control	13.5383*	3.35301	.001	4.5078	22.5687
		Zirconia	-6.3057	3.35301	.254	-15.3362	2.7247
		Titanium	.3120	3.35301	1.000	-8.7184	9.3424

Table 4: Basic data of surface hardness

	Group	Mean	Std. Deviation	N
S H Heatcure Artificial Saliva	Control group	33.6050	.96070	10
	Zirconia group	36.3060	1.39533	10
	Titanium group	34.2860	.93410	10
	Aluminum group	35.1410	.59708	10
	Total	**34.8345**	**1.41066**	**40**
S H Heatcure Distilled Water	Control group	33.3850	1.72492	10
	Zirconia group	36.6370	2.50563	10
	Titanium group	34.0630	1.46719	10
	Aluminum group	34.6070	1.36043	10
	Total	**34.6730**	**2.13781**	**40**

Based on observed means. The error term is Mean Square (Error) = 56.213

Table 5: Two-way analysis of variance (ANOVA) for surface hardness of heat polymerized PMMA provisional resin in distilled water for 24 hours and two weeks in artificial saliva after fabrication

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	S H Heatcure Artificial Saliva	40.718[a]	3	13.573	13.245	.000
	S H Heatcure Distilled Water	58.927[b]	3	19.642	5.927	.002
Intercept	S H Heatcure Artificial Saliva	48537.696	1	48537.696	47366.403	.000
	S H Heatcure Distilled Water	48088.677	1	48088.677	14509.734	.000
Group	S H Heatcure Artificial Saliva	40.718	3	13.573	13.245	.000
	S H Heatcure Distilled Water	58.927	3	19.642	5.927	.002
Error	S H Heatcure Artificial Saliva	36.890	36	1.025		
	S H Heatcure Distilled Water	119.312	36	3.314		
Total	S H Heatcure Artificial Saliva	48615.304	40			
	S H Heatcure Distilled Water	48266.917	40			
Corrected Total	S H Heatcure Artificial Saliva	77.608	39			
	S H Heatcure Distilled Water	178.239	39			

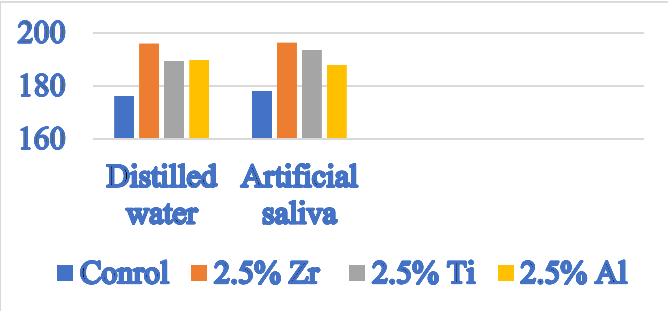
a. R Squared = .525 (Adjusted R Squared = .485)
b. R Squared = .331 (Adjusted R Squared = .275)

Table.6: Tukey´s Post Hoc Test for surface hardness of heat polymerized PMMA provisional resin in distilled water for 24 hours and two weeks in artificial saliva after fabrication

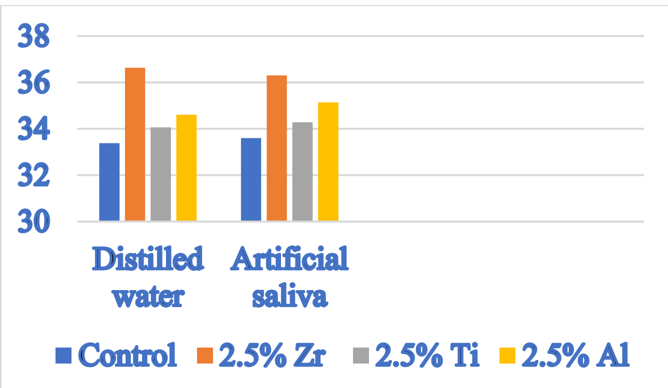
Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
S H Heatcure Artificial Saliva	Control	Zirconia	-2.7010*	.45271	.000	-3.9202	-1.4818
		Titanium	-.6810	.45271	.446	-1.9002	.5382
		Aluminum	-1.5360*	.45271	.009	-2.7552	-.3168
	Zirconia	Control	2.7010*	.45271	.000	1.4818	3.9202
		Titanium	2.0200*	.45271	.000	.8008	3.2392
		Aluminum	1.1650	.45271	.066	-.0542	2.3842
	Titanium	Control	.6810	.45271	.446	-.5382	1.9002
		Zirconia	-2.0200*	.45271	.000	-3.2392	-.8008
		Aluminum	-.8550	.45271	.251	-2.0742	.3642
	Aluminum	Control	1.5360*	.45271	.009	.3168	2.7552
		Zirconia	-1.1650	.45271	.066	-2.3842	.0542
		Titanium	.8550	.45271	.251	-.3642	2.0742
S H Heatcure Distilled Water	Control	Zirconia	-3.2520*	.81415	.002	-5.4447	-1.0593
		Titanium	-.6780	.81415	.839	-2.8707	1.5147
		Aluminum	-1.2220	.81415	.447	-3.4147	.9707
	Zirconia	Control	3.2520*	.81415	.002	1.0593	5.4447
		Titanium	2.5740*	.81415	.016	.3813	4.7667
		Aluminum	2.0300	.81415	.078	-.1627	4.2227
	Titanium	Control	.6780	.81415	.839	-1.5147	2.8707
		Zirconia	-2.5740*	.81415	.016	-4.7667	-.3813
		Aluminum	-.5440	.81415	.908	-2.7367	1.6487
	Aluminum	Control	1.2220	.81415	.447	-.9707	3.4147
		Zirconia	-2.0300	.81415	.078	-4.2227	.1627
		Titanium	.5440	.81415	.908	-1.6487	2.7367

Based on observed means. The error term is Mean Square (Error) = 3.314.

Graph.1: Comparison of flexural strength of heat polymerized PMMA provisional resin in distilled water for 24 hours after fabrication and in artificial saliva for 2 weeks after fabrication



Graph.2: Comparison of surface hardness of heat polymerized PMMA provisional resin in distilled water for 24 hours after fabrication and in artificial saliva for 2 weeks after fabrication



DISCUSSION

The provisional restorative material for fixed dental prosthesis must have adequate strength to withstand the masticatory load. Polymethylmethacrylate resins are the most commonly used material for temporary restorative material even though they had less strength and poor hardness [12]. If the temporary prosthesis is used for prolonged time like during the prosthetic phase of dental implants and reconstructive procedures, for which the mechanical properties have an important role [13]. Provisional restorations with more flexural strength are mandatory for patients requiring endodontic and periodontal therapy with fixed prosthetic treatment [14].

The flexural strength of interim resin materials may be influenced by saliva, food components, beverages, and interactions among these materials. The purpose of storing samples in artificial saliva for 2 weeks was to simulate the intraoral condition partially [15-19].According to Thomson et al, the storage medium like artificial saliva would not affect the microhardness, impact strength, or flexural strength of interim polymeric restorative materials [20].Zirconia nanoparticles possesses strong ionic interatomic bonding, with ceramics, acrylic and restorative resins which showed its improvement in hardness and strength properties [21].Titanium alloy has higher strength, less dense, less weight, less shrinkage, good mechanical properties and resistant to corrosion, and biocompatible. Titanium oxide is used, since it increases the surface hydrophobicity, reduces the adherence of biomolecules, aids in coloring has antimicrobial properties and improves mechanical properties of PMMA resins [22].

The mechanical properties of all resins used in dentistry are tested using 3-point bending test. [10] Vickers indentation as a convenient tool for evaluating the hardness, viscoelastic, and other responses of rigid polymers [11]. The addition of modified nano-ZrO_2 to improve mechanical properties has shown to achieve maximum radio-opacity with minimum effect on mechanical properties. Zirconia (ZrO_2) has excellent biocompatible material also it is a white color material, hence there is less chance of alteration in esthetics [23].

The nano-ZrO_2 particle sizes, their distribution within the repair material, and the salinization process, along with the joint's surface design, would have attributed to increase the flexural strength. In addition, the transformation toughening causes tetragonal to monoclinic phase exchange of Zirconia nanoparticles resulting in absorption of energy during propagation of crack. While the phase changes from tetragonal to monoclinic, ZrO_2 crystals expansion of kept the crack under compressive stress, which tend to the break the propagation of crack [24].

The amount of metal oxides fillers incorporated to be minimal which enable a low density and light weight acrylic resin. Also, the dimensions and scattering of filler particles in the polymer matrix are responsible for improved mechanical properties of composites resins [25]. Previous literature evidenced of increased flexural strength with the incorporation of Titanium oxide nanoparticles. Control, 1%, 2%, 5% titanium nanoparticles had a mean of 176.06 ± 47.06MPa, 182.51 ± 22.29MPa, 204.75 ± 29.42MPa, and 223.43 ± 49.27MPa respectively and also proved that flexural strength of heat polymerized polymethylmethacrylate resin was decreased after 5% reinforcement with Al_2O_3 nanoparticles. 2.5% of the filler were selected for this study [26]. The mechanism behind the increase in the flexural strength is due to transformation toughening. Al_2O_3 exists in hexagonal alpha phase at the higher temperatures. When the stresses develop and there is propagation of microcracks, the transformation phenomenon begins, which reduces energy for crack generation. Therefore, proper distribution of the nanoparticles in the matrix can cease formation of cracks [27-29].

According to this study, the flexural strength of heat polymerizing provisional PMMA resin in distilled water are 176.11MPa, 195.96MPa, 189.34MPa, and 189.65MPa respectively. The flexural strength of heat polymerizing provisional PMMA resin in artificial saliva are 178.18MPa, 196.29MPa, 193.49MPa, and 187.89MPa respectively. (Group 1) On comparing the flexural strength of 2.5% Zirconia,2.5% Titanium oxide and 2.5% Aluminum oxide nanoparticles reinforcement with control in distilled water and 2 weeks in artificial saliva showed statistically significant value $P<0.05$ with control. Hence the flexural strength for heat cure PMMA provisional resin reinforced with 2.5% of Zirconia and Titanium oxide nanoparticles group showed higher values than Aluminum oxide nanoparticles group in artificial saliva.

The surface hardness of heat polymerizing provisional PMMA resin without nanoparticles,2.5% zirconia, 2.5% Titanium oxide, 2.5% Aluminum oxide nanoparticles were 33.3,36.3,34,34.6 VHN respectively. On comparing the surface hardness showed statistically significant value $P<0.05$ with control. Zirconia and Titanium oxide nanoparticles reinforced groups of heat polymerizing PMMA provisional resin showed higher values than Aluminum group (in distilled water and 2 weeks in artificial saliva). (Graph 2)

Limitations of this study are that Zirconia nanoparticles are expensive. The properties of provisional restoration were affected by form, aggregation, surface treatment, and storage media used to simulate the clinical situations in oral environment. Hence storage for prolonged time would give better results of oral conditions.

Clinical implication

Zirconia and Titanium oxide nanoparticles reinforced conventional provisional PMMA resin showed significantly better mechanical properties of recently marketed provisional PMMA resin materials. Hence Zirconia and Titanium oxide nanoparticles can be recommended for reinforcement of heat polymerizing PMMA provisional resin to enhance the flexural strength and surface hardness thereby increase the life span of provisional restoration in clinical practice.

CONCLUSION

Within the limitations of the study the authors concluded that

1. The flexural strength of 2.5% Zirconia,2.5% Titanium oxide and 2.5% Aluminum oxide nanoparticles reinforced heat polymerized PMMA provisional resin after 24 hours fabrication in distilled water and 2 weeks of fabrication in artificial saliva were 195.96,189.34, 189.65, and 196.29, 193.49, and 187.89 respectively. The 2.5% Zirconia nanoparticles reinforced heat polymerized PMMA provisional resin showed statistically significant flexural strength compared to 2.5% Titanium oxide and 2.5% Aluminum oxide nanoparticles reinforced provisional PMMA resin
2. The surface hardness of 2.5% Zirconia,2.5% Titanium oxide and 2.5% Aluminum oxide nanoparticles reinforced of heat polymerized PMMA provisional resin after 24 hours of fabrication in distilled water were 36.6, 34, 34.6 VHN and 2 weeks of fabrication in artificial saliva were 36.3, 34.2, 34.6 VHN thus, , 2.5% Zirconia nanoparticles heat polymerized PMMA provisional resin showed statistically significant surface hardness compared to 2.5% Titanium oxide and 2.5% Aluminum oxide nanoparticles reinforced PMMA provisional resin.

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How to cite this article

Asmath Jehan, Ahila Singaravel Chidambaranathan, Muthukumar Balasubramanium, 2022. Flexural strength, Heat activated PMMA resin, Provisional restoration, Surface hardness. J. Med. P'ceutical Allied Sci. V 11 - I 1, Pages- 4340 – 4348. doi: 10.22270/jmpas.V11I1.2171.