

EVALUATION OF IMPACT STRENGTH OF POLYMETHYL METHACRYLATE BASED AUTO-POLYMERIZED AND HEAT POLYMERIZED PROVISIONAL RESTORATIVE MATERIALS REINFORCED WITH ZIRCONIA AND ALUMINUM OXIDE

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ABSTRACT:

Statement of problem: Provisional prostheses are subject to flexure under function. Fracture toughness, hardness and impact strength of provisional restorations are of important concern for the restorative dentist. Water sorption of a material is directly related to the transverse strength.

Objective: To evaluate the impact strength and water sorption of methyl methacrylate based auto polymerized and heat polymerized provisional restorative materials reinforced with zirconia and aluminum oxide

Materials and method: A metal mold of standard dimension is fabricated from which 140 samples were fabricated using auto polymerized and heat polymerized provisional restorative materials impregnated with zirconia powder and aluminum oxide powder at pre polymerized state at a mixing ratio of 0, 1%, 3% and 5% by volume. Provisional restorations with 0% zirconia and 0% aluminum acts as control group. Completed provisional crowns are then subjected to testing for impact strength and water sorption

Results: Impact strength of auto polymerized and heat polymerized PMMA reinforced with 5% zirconia and aluminum oxide is more compared to other groups. Water sorption of both cold cure and heat cure PMMA control groups and 1% zirconia and aluminum reinforced groups, there is significance after 7 days, but water sorption of 5% zirconia and 5% aluminum reinforced PMMA groups did not varied significantly.

Conclusion: Reinforcement of 5% zirconium and 5% aluminum oxide to auto polymerized and heat polymerized poly methyl methacrylate groups showed significant increase in their impact strength and reduced water sorption.

Keywords: Provisional restorations, poly [methyl methacrylate] resin, impact strength, water sorption, zirconia, alumina.



INTRODUCTION:

Definitive crowns and fixed partial dentures are usually multiple dental visit procedures which require provisional restoration to mimic the final planned

restoration. Functions of provisional restoration includes maintaining the comfort of the patient and tooth vitality, occlusion and positional stability of the

tooth, gingival health and contour, esthetics. Commonly used materials are polymethyl methacrylate (self or heat cured), polyethyl methacrylate (eg Snap, Trim), bis acryl composite (eg Protemp, Quicktemp), urethane dimethacrylate (light cured), restorative composite material. However low impact strength of an acrylic resin is a potential disadvantage.^[1,2] Various methods have been attempted to increase material strength of provisional restorative material like reinforcing it by adding fillers such as zirconia, silver, copper, aluminum particles, calcium carbonate, glass fibers, carbon fibers which acts by co-polymerization and cross – linking of resin materials.^[3] Zirconium oxide is a polymorphic material which has high flexural strength and fracture toughness as a result of transformation toughening. Besides its high hardness and good thermal properties, aluminum oxide (Al₂O₃) was proved to be biocompatible material which makes it the material of choice to reinforce acrylic resins in order to improve its strength properties. The present in vitro study was done to evaluate impact strength and water sorption of methyl methacrylate based auto polymerized and heat polymerized provisional restorative materials reinforced with zirconia and aluminum oxide at various proportions.^[4,5]

MATERIALS AND METHODS:

The metallic master mold of standard dimensions 10x 2.5x 55mm- ASTM A370 (fig 1) was selected and duplicated using

addition silicone putty material. Provisional materials selected were methacrylate based auto polymerized provisional crown material (DPI self-cure tooth molding powder Dental Products of India) and heat polymerized provisional crown material (Dental Products of India). 140 samples of similar dimensions were fabricated with provisional restorative materials. Out of which 70 samples were fabricated with auto polymerized PMMA and 70 samples with heat polymerized PMMA. Standard dies were flaked to obtain mould space for acrylic specimen preparation (fig 2). Zirconia and alumina powder were admixed to pre polymerized acrylic polymer powder in 0%, 1%, 3%, and, 5% by weight which was weighed in an electronic sensitive balance. Heat cure acrylic resin was then proportioned with zirconia and aluminum oxide at various concentrations with mixture of monomer and polymer in ratio of 1:2.5 by weight according to standard dental laboratory usage as described by McCabe and Walls.

The flask was immersed in an acrylizer (Unident, Mumbai, India) at room temperature for curing. The temperature was raised slowly up to 74°C and held for 2 hours, then raised to 100°C and was maintained for 1 hour. Acrylic specimens were finished and polished. The dimensions and quality of each specimen were verified. A total of 280 specimens were fabricated with 20 specimens for each group (n = 20) (fig 3).

To evaluate impact strength 10 samples each of two provisional crown materials with 0%, 1%, 3%, 5% Zirconia and 0%, 1%, 3%, 5% Alumina were stored at room temperature. Each specimen was subjected to Charpy's impact test. The load is applied as an impact blow from a weighted pendulum of S2 scale in air at $23 \pm 2^\circ\text{C}$. Before testing, pendulum was released to freely swing in the air to record the air resistance encountered by free-swinging pendulum. Air resistance of 0.6 Joules was recorded. The readings were taken on S2 scale where pointer was stabilized after swing. The specimen was clamped in position precisely. Pendulum was released and reading indicating energy absorbed to break the specimens on S2 scale was recorded. All the specimens were tested in the same manner. Impact strength of specimen was calculated by using following formula

$$IS = E/b_n d \times 10^3$$

Where, E is the energy absorbed by specimen with impact resistance in Joules, b_n = Test specimen width in millimeter and d is the specimen thickness. The impact strength value of each specimen was noted.

To evaluate water sorption another 10 samples each of two provisional crown materials with 0%, 1%, 3%, 5% Zirconia and 0%, 1%, 3%, 5% alumina were conditioned in water for 7 days at 37°C and placed in water at 23°C for 1 hour prior to testing. Amount of weight gain was calculated by difference between initial weight and final weight of each

specimen after one week using sensitive balance having sensitivity of 0.001gm and capacity of 10 gms (fig 4). These samples were later subjected to Charpy's impact strength test after water sorption.

The null hypothesis in the present study is that there is no difference in impact strength of auto polymerized and heat polymerized PMMA resin.

RESULTS:

The mean values of auto polymerized and heat polymerized reinforced with zirconia and alumina were analyzed using Mann Whitney U test and Wilcoxon signed rank test which were used to determine whether significant differences existed between the means of the experimental groups. Impact strength of specimen tested was summarized in table 1. It is seen that the heat polymerized PMMA reinforced with 5% zirconia specimen presents the highly significant impact strength followed by heat polymerized PMMA reinforced with 5% alumina specimen with p value of <0.01 and auto polymerized PMMA reinforced with 3% zirconia and 3% alumina respectively with p value of <0.05 .

Impact strength of specimen tested after water sorption was summarized in table 2. It was observed that heat polymerized PMMA reinforced with 5% zirconia specimen presents the highly significant impact strength followed by heat polymerized PMMA reinforced with 5% alumina specimen with p value of <0.01

On comparison of impact strength within control, zirconia and alumina admixed auto polymerized and heat polymerized PMMA groups, graph 1 it was shown that heat polymerized PMMA reinforced with 5% zirconia specimen presents the high impact strength followed by heat polymerized PMMA reinforced with 5% alumina specimen, auto polymerized PMMA reinforced with 3% zirconia and auto polymerized PMMA reinforced with 3% alumina.

On comparison of impact strength after water sorption within control, zirconia and alumina admixed auto polymerized and heat polymerized PMMA groups, graph 2 it was shown that heat polymerized PMMA reinforced with 5% zirconia specimen presents the high impact strength followed by heat polymerized PMMA reinforced with 5% alumina specimen, auto polymerized PMMA reinforced with 3% zirconia and auto polymerized PMMA reinforced with 3% alumina.

There was significant decrease in impact strength of control group along with PMMA reinforced with 1%, and 3% zirconia and alumina in both heat polymerized and auto polymerized specimen.

On comparison of water sorption of control, zirconia and alumina admixed auto polymerized and heat polymerized PMMA groups, it was shown that heat polymerized PMMA reinforced with 5% zirconia specimen presents the least water sorption followed by heat

polymerized PMMA reinforced with 5% alumina specimen with p value of 0.1 and 0.5 respectively (table 3).

DISCUSSION:

The materials selected for this study possess advantages and disadvantages. PMMA resin shows satisfactory overall physical properties, including marginal finish and the potential to impart and maintain polish. Polymerization shrinkage, exothermic setting reaction, and the irritation associated with monomer are among the material's disadvantages, and relatively lower levels of fracture toughness have been reported. Moreover, the working and resultant biophysical properties of set auto polymerizing PMMA can be influenced by the monomer-powder ratio, which can vary from mix to mix and from dentist to dentist.^[3,5,6]

Zirconium oxide is a polymorphic material which has high flexural strength and fracture toughness as a result of transformation toughening. Aluminum oxide, commonly referred to as alumina, possesses strong ionic interatomic bonding, giving rise to its desirable material characteristics. It can exist in several crystalline phases, which all revert to the most stable hexagonal alpha phase at elevated temperatures. This is the phase of particular interest for structural applications. Alpha phase alumina is the strongest and stiffest of the oxide ceramics. Its high hardness, excellent dielectric properties, refractoriness, and good thermal

properties make it the material of choice for a wide range of applications.^[2,7,8]

A study by John et al., showed that 68% of the acrylic resin fracture within a few years after fabrication, which may be primarily because of impact or fatigue failure. Impact fatigue may occur in the mouth due to repeated impacts from chewing. This ultimately fractures the restoration in the mouth and causes inconvenience to both the dentist and the patients. So in order to overcome these failures many authors tried reinforcing PMMA with various materials likely glass, aramid and nylon fibers.^[9,10,11]

The present study was done by reinforcing PMMA with 0%, 1%, 3%, 5% Zirconia and 0%, 1%, 3%, 5% alumina which was widely recommended by many of the authors due to their positive properties like good thermal properties, high hardness and refractoriness. However, few limitations of the use of these material includes decrease in tensile strength, decreased esthetic appearance when used in higher proportions.

The concept of self-reinforcement has been studied recently by Jagger, Harrison and Jand. Unfortunately the effect of the addition of untreated and surface treated chopped PMMA fibers did not produce a significant improvement in either the transverse strength or impact strength of acrylic resin. They found that the fiber arrangement in terms of fiber displacement and inter fiber spacing,

may be important factors in the success of the reinforcement.^[12,13,21]

In the present it was observed that impact strength of auto polymerized and heat polymerized PMMA reinforced with 5% zirconia is greater than that of their respective control groups. W. Panyayong et al, in his study showed that impact strength of provisional restorative materials admixed with zirconia is higher than traditional resins.^{1,16} This might be attributed to the presence of reinforced zirconia and alumina powder which provide strength and stiffness to the specimen, resulting in higher absorption of energy compared with un-reinforced specimens.

In the present it was observed that impact strength of auto polymerized and heat polymerized PMMA reinforced with 5% aluminum oxide is greater than that of their respective control groups. Study conducted by Pooja, Ravindranath, Gopinath et al, showed that impact strength of provisional restorative materials admixed with zirconia is higher than traditional resins. This might be attributed to the presence of reinforced zirconia and alumina powder which provide strength and stiffness to the specimen, resulting in higher absorption of energy compared with un-reinforced specimens.^[14,15,17,18,19]

In the present study it was observed that zirconia and alumina reinforced heat polymerized PMMA specimen showed greater impact strength compared to auto polymerized PMMA. This might be

attributed due to presence of least amount of residual monomer content in heat polymerized zirconia and alumina reinforced PMMA specimen.^[19,20,21]

In the present study it was observed that 5% zirconia and alumina reinforced heat and auto polymerized PMMA specimen showed least water sorption. The possible reason for decrease in water sorption with addition of 5% zirconia and 5% alumina powder was attributed to

proper distribution of zirconia and alumina spheres within resin and these act as potential fillers in the resin matrix.

CONCLUSION:

Within the limitations of the study, reinforcement of 5% zirconium and 5% aluminum oxide to auto polymerized and heat polymerized poly methyl methacrylate groups showed significant increase in their impact strength and reduced water sorption.

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FIGURES:

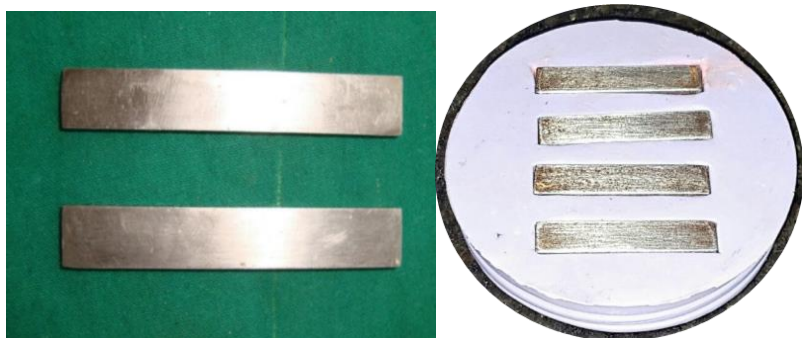


Fig 1: The metallic master mold of standard dimensions 10x 2.5x 55mm- ASTM A370 and flasked dies



Fig 2: Standard dies were flasked to obtain mould space for acrylic specimen preparation

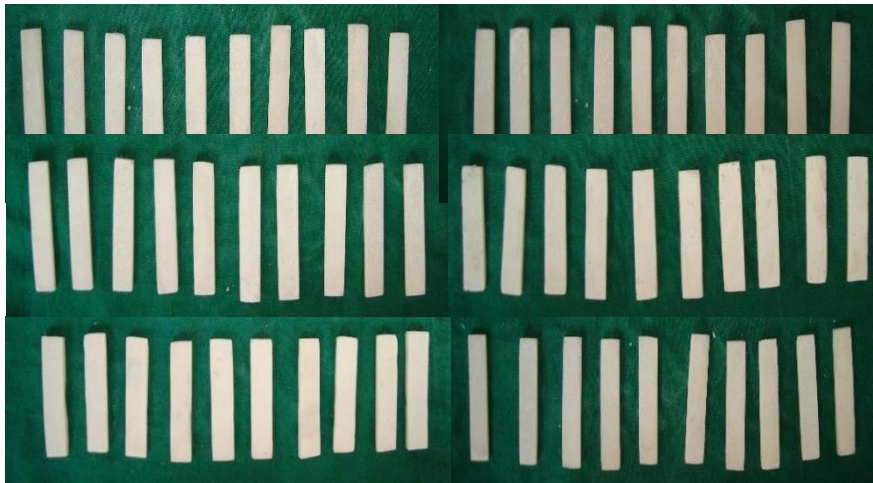


Fig 3: Acrylic specimens were finished and polished



Fig 4: Sensitive balance having sensitivity of 0.001gm and capacity of 10 gms

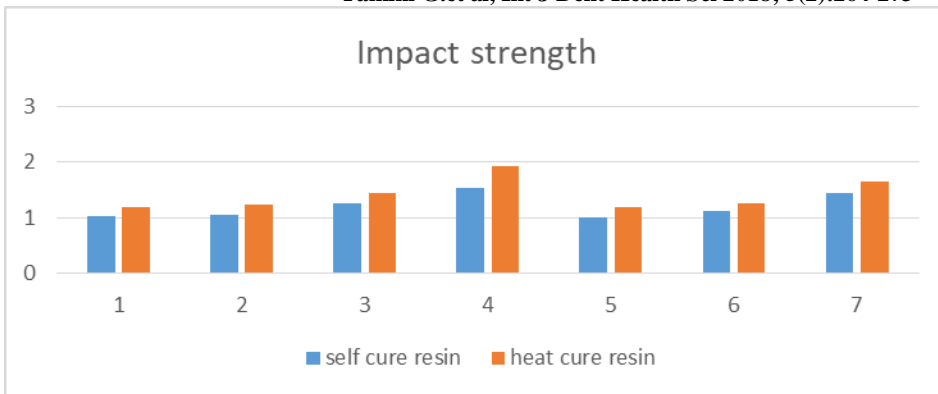
TABLES:

Impact strength		P-value	Inference
Auto polymerized Control PMMA	1 % Zr + PMMA	0.57	NS
	3% Zr + PMMA	<0.05	S
	5% Zr + PMMA	<0.01	HS
	1% Al + PMMA	0.09	NS
	3% Al + PMMA	<0.05	S
	5% Al + PMMA	<0.01	HS
Heat polymerized Control PMMA	1 % Zr + PMMA	0.49	NS
	3% Zr + PMMA	<0.05	S
	5% Zr + PMMA	<0.01	HS
	1% Al + PMMA	0.08	NS
	3% Al + PMMA	<0.05	S
	5% Al + PMMA	<0.01	HS

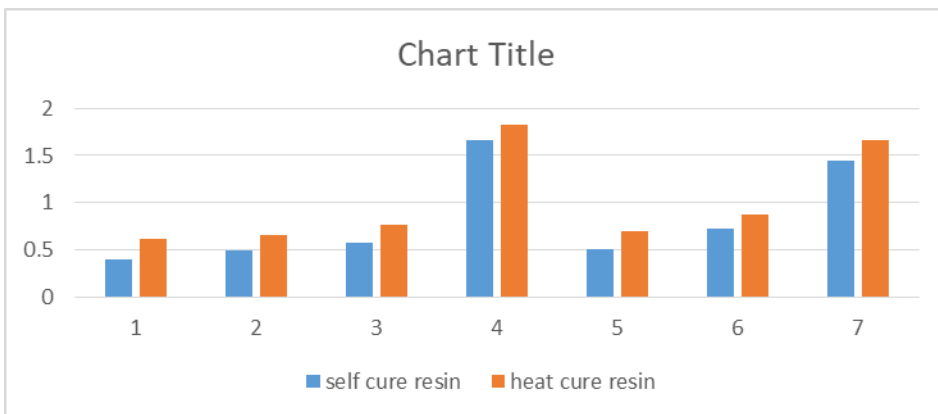
Table 1: comparison of impact strength within control, zirconia and alumina admixed auto polymerized and heat polymerized PMMA groups.

Impact strength after water sorption		P-value	Inference
Auto polymerized Control PMMA	1 % Zr + PMMA	0.65	NS
	3% Zr + PMMA	0.38	NS
	5% Zr + PMMA	<0.01	HS
	1% Al + PMMA	0.07	NS
	3% Al + PMMA	0.42	NS
	5% Al + PMMA	<0.01	HS
Heat polymerized Control PMMA	1 % Zr + PMMA	0.56	NS
	3% Zr + PMMA	0.23	NS
	5% Zr + PMMA	<0.01	HS
	1% Al + PMMA	0.06	NS
	3% Al + PMMA	0.32	NS
	5% Al + PMMA	<0.01	HS

Table 2: comparison of impact strength after water sorption within control, zirconia and alumina admixed auto polymerized and heat polymerized PMMA groups.



Graph 1: comparison of impact strength within control, zirconia and alumina admixed auto polymerized and heat polymerized PMMA groups.



Graph 2: comparison of impact strength after water sorption within control, zirconia and alumina admixed auto polymerized and heat polymerized PMMA groups.

Water sorption	Pre Weight		Post Weight		P-value	Inference
	Mean	SD	Mean	SD		
Control PMMA	1.20	0.01	1.29	0.05	<0.05	S
+ 1% Zr	1.26	0.24	1.36	0.04	<0.05	S
+ 3% Zr	1.19	0.01	1.25	0.03	<0.05	S
+ 5% Zr	1.18	0.02	1.20	0.01	0.1	NS
+ 1% Al	1.01	0.05	1.12	0.05	<0.05	S
+ 3% Al	1.08	0.02	1.16	0.02	<0.05	S
+ 5% Al	1.24	0.03	1.44	0.06	0.5	NS

Table 3: Comparison of Water sorption mean between Pre & Post weight in Control PMMA, 1 % Zr PMMA, 3% Zr PMMA, 5% Zr, 1 % Al PMMA, 3% Al PMMA, 5% Al PMMA by using Wilcoxon signed rank test.