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A Comparative Evaluation of Impact Strength, Compressive Strength, Tensile Strength, Hardness and Dimensional accuracy of Autopolymerized, Postpolymerized Microwave Exposed Autopolymerized and Heat-Cured Denture Base Resins- An in Vitro Study

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Abstract: Several denture based materials have been used with a wide range of applications. Several techniques have been used in recent time to improve its properties for better durability, strength and working. To compare Impact Strength, Compressive Strength, Tensile Strength, Hardness and Dimensional accuracy of autopolymerized, postpolymerized microwave exposed autopolymerized and heat-cured denture base resins. Specimens were prepared by different modes of polymerization using autopolymerization technique, microwave post-polymerization treatment of autopolymerized acrylic resin and conventional water bath technique. The specimens were then subjected to various tests to evaluate strength (Impact, compressive, Tensile) and Hardness. There is statistically significant difference was found between mean impact strength and compressive strength of autopolymerized, postpolymerized microwave exposed autopolymerized and heat-cured denture base resin. There is no statistically significant difference between mean tensile strength of autopolymerized acrylic resin and postpolymerized microwave exposed autopolymerized acrylic resin (p=1.000) but a statistically significant difference was found between mean tensile strength of autopolymerized acrylic resin and heat-cured denture base resins (p=0.001). There was a statistically significant difference between mean Rockwell Hardness Number of autopolymerized acrylic resin and postpolymerized microwave exposed autopolymerized acrylic resin (p=0.005). A statistically significant difference was also found between mean Rockwell Hardness Number of postpolymerized microwave exposed autopolymerized acrylic resin and heat-cured denture base resins (p=0.001). Similarly, there was statistically significant difference was found between mean Rockwell Hardness Number of autopolymerized acrylic resin and heat-cured denture base resins (p=0.03). Comparison of mean linear dimensional change between autopolymerized and postpolymerized microwave exposed autopolymerized denture base resins showed no statistically significant difference in the mean dimensional change between the autopolymerized and postpolymerized microwave exposed autopolymerized denture base resins (p=0.051). Heat-cured acrylic resin exhibited the maximum values for Impact strength, Compressive Strength, Tensile Strength, Hardness and Dimensional Accuracy and Impact Strength of autopolymerized acylic resin improved after microwave postpolymerization treatment. Whereas, Hardness is decreased and Dimensional accuracy remained unaffected after the microwave postpolymerization treatment of autopolymerized acrylic resin.
Keywords: Autopolymerized resins, postpolymerized resins, heat-cured denture base resins.

INTRODUCTION

Acrylic resins are used as denture base materials since 1937. Physical and mechanical properties characterize the durability that is desirable in a finished denture. Out of acrylic denture base resins available, Poly methyl-methacrylate (PMMA), is most commonly used to make removable complete and partial dentures. This dominance has been supported by physical, mechanical and esthetic properties of PMMA, as well as material's availability, reasonable cost, and ease of manipulation [1]. Virtually, dentures are constructed from conventional polymer/monomer processed by heat water-bath system and compression molding technique [2].

Acrylic resins and their curing processes have been modified in order to improve the physical and mechanical properties of materials, and also to afford the technical work of the professionals. Various activation modes of polymerization have been used: heat, visible light, and microwave energy [3]. Chemical activators also may be used to induce denture base polymerization. Chemical activation does not require the application of thermal energy, and therefore may be completed at room temperature. As a result, chemically activated resins often are referred to as cold-curing, self-curing, or autopolymerizing resins [4].

Polymerization of heat-cured PMMA is usually carried out in a temperature-controlled water bath for at least 9 hours. However, the use of microwave energy to polymerize PMMA decreases the time to three minutes only, producing acrylic resin bases with the same quality as those polymerized by water bath technique [2]. The advantages of microwave heating over conventional heating are: (1) the inside and outside of substance are almost equally heated and (2) temperature rises rapidly [5, 6].

From the polymerization reaction point of view, the degree of conversion is the most important characteristic, on account of the high residual monomer levels that could be unreacted. Its presence has an adverse effect on the physical and mechanical properties as well as on biocompatibility. Various authors have compared denture base resins depending upon their properties [3]. Therefore, an in vitro study was to determine the effect of microwave radiation on the autopolymerized acrylic resin to enhance the properties of the product and find its use as an acceptable regular denture base material and we also attempted to compare the physical and mechanical properties of autopolymerized, post-polymerized microwave exposed autopolymerized and heat-cured denture base resins.

MATERIALS AND METHODS

To test and compare the various physical and mechanical properties of PMMA denture base resin, the specimens were prepared by different modes of polymerization in the Department of Prosthodontics & Crown and Bridge.

Preparation of moulds and specimen

The study was conducted by using two commercially available heat- cured (Trevalon / Dentsply) and cold-cured acrylic resins. The specimens used in the study were fabricated from the specially designed stainless steel moulds of different shapes and dimension. Total 90 test specimens were prepared to test the various properties of acrylic resins. These were further divided into three groups (each having 30 specimens) based upon their processing techniques.

Group A: 10 specimens each of three different shapes viz. plates, cubes, and dumbbells were prepared in autopolymerized acrylic resin

Group B: 10 specimens each of three different shapes were prepared in autopolymerized acrylic resin and were further post-polymerized by exposing to microwave radiation.

Group C: 10 specimens each of three different shapes were prepared in heat-cured acrylic resin.

A specially designed stainless steel flask was prepared for the processing of acrylic resin plate and flat dumbbell specimens of given dimensions. The specimens were processed by the autopolymerization technique, microwave post-polymerization treatment of autopolymerized acrylic resin and conventional water bath technique. The specimens were subjected to various tests in CIPET BHOPAL for Impact Strength in KgF (Impact Strength Testing Machine), Compressive strength in N/mm2 (Universal Testing Machine Model – UTN-60 and Make – FIE), Tensile strength in N/mm2 (Tensile Strength Testing Machine Model – 1.3D-300 KGF (DIGITAL) and Make – KMI/SHANTA), Hardness test in RHN (Rockwell Hardness Testing Machine Model – MSM and Make – C-45/2, MIDC Area, Miraj), Dimensional Accuracy using Digital Vernier Calliper

All the data obtained from the above tests were statistically analyzed using SPSS 11. One-way ANOVA was used to determine whether there were any significant differences between the means of three or more independent (unrelated) groups followed by Post Hoc Tukey Test. p- value less than 0.05 was considered to be statistically significant at 95% confidence interval.

RESULTS

Table-1 shows the mean values of Impact Strength, Compressive Strength, Tensile Strength, Rockwell Hardness Number and Dimensional Accuracy for a different type of resin specimens.

Table-1: Mean values of Impact Strength, Compressive Strength, Tensile Strength, Rockwell Hardness Number and Dimensional Accuracy for different type of resin specimens.

Type Of Specimens	Mean Impact Strength (KgF)	Mean Compressive Strength (N/mm^2)	Mean Tensile Strength (N/mm^2)	Mean Rockwell Hardness Number (RHN)	Mean Dimensional Accuracy (mm)
Autopolymerized Acrylic Resin	45	45.20	5.98	86	-
Autopolymerized Acrylic Resin Specimens Exposed To Microwave Radiation	48	39.60	6.09	82.2	49.93
Heat-Cured Denture Base Resin	50	102.40	7.001	89	-

IMPACT STRENGTH

Table-2A Shows comparison of mean impact strength of autopolymerized, postpolymerized microwave exposed autopolymerized and heat-cured denture base resins. Analysis of Variance (One-way ANOVA) was applied to determine the comparison between three groups. A statistically significant difference was found (F = 106.875, p <0.001) between the three testing groups.

Table-2A: Comparison of Mean Impact Strength of autopolymerized, postpolymerized microwave exposed autopolymerized and heat cured denture base resins (One - Way ANOVA)

Study Samples	Samples (N)	Mean	Std. Deviation	F	p - value	Significance
Autopolymerized Acrylic Resin	10	45.00	0.471	106.875	<0.001	
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	10	48.00	0.471			Significant
Heat Cured Denture Base Resins	10	50.00	1.154			

($p \leq 0.05$ – Significant, CI = 95 %)

One-way ANOVA was followed by Post Hoc Tukey's Test (Table-2B) and a statistically significant difference was found between mean impact strength of autopolymerized acrylic resin and postpolymerized microwave exposed autopolymerized acrylic resin (p<0.001). A statistically significant difference was also found between mean impact strength of post-polymerized microwave exposed autopolymerized acrylic resin and mean impact strength of heat-cured denture base resins (p<0.001). Similarly, there was a statistically significant difference between mean impact strength of autopolymerized acrylic resin and mean impact strength of heat-cured denture base resins (p<0.001)

Table-2B: Post Hoc Tukey Test

Study Groups	Autopolymerized Acrylic Resin Samples	Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	Heat Cured Denture Base Resin Samples
Autopolymerized Acrylic Resin Samples	-	<0.001*	<0.001*
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	<0.001*	-	<0.001*

* The mean difference is significant at the 0.05 level.

COMPRESSIVE STRENGTH

Table-3A Shows comparison of the mean compressive strength of autopolymerized, postpolymerized microwave exposed autopolymerized and heat-cured denture base resins. Analysis of Variance (One-way ANOVA) was applied to determine the comparison between three groups. A statistically significant difference was found (F = 179.738), (p <0.001) in the mean compressive strength between the various testing groups.

Table-3A: Comparison of Mean Compressive Strength of autopolymerized, postpolymerized microwave exposed autopolymerized and heat cured denture base resins (One – Way ANOVA)

Study Samples	Samples (N)	Mean	Std. Deviation	F	p - value	Significance
Autopolymerized Acrylic Resin	10	45.200	10.336	179.738	<0.001	
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	10	39.600	8.315			Significant
Heat Cured Denture Base Resins	10	102.400	5.059			

(p ≤ 0.05 – Significant, CI = 95 %)

One-way ANOVA was followed by Post Hoc Tukey's Test (Table-3B) and it was found that there was no statistically significant difference between the mean compressive strength of autopolymerized acrylic resin and postpolymerized microwave exposed autopolymerized acrylic resin (p=0.415).

Table-3B: Post Hoc Tukey Test

Study Groups	Autopolymerized Acrylic Resin Sample	Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	Heat Cured Denture Base Resin Samples
Autopolymerized Acrylic Resin Samples	-	**<0.451**	**<0.001***
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	**<0.451**	-	**<0.001***

* The mean difference is significant at the 0.05 level.

A statistically significant difference was found between mean compressive strength of autopolymerized acrylic resin and heat-cured denture base resins (p<0.001). Similarly, there was statically significant difference was also found between mean compressive strength of postpolymerized microwave exposed autopolymerized acrylic resin and heat-cured denture base resins (p<0.001)

TENSILE STRENGTH

Table-4A Shows comparison of the mean tensile strength of autopolymerized, postpolymerized microwave exposed autopolymerized and heat-cured denture base resins. Analysis of Variance (One-way ANOVA) was applied to determine the comparison between the mean tensile strength of three groups. A statistically significant difference was found (F = 10.563, p<0.001) in the mean tensile strength between the various testing groups.

Table-4A: Comparison of Mean Tensile Strength of autopolymerized, postpolymerized microwave exposed autopolymerized and heat cured denture base resins (One – Way ANOVA)

Study Samples	Samples (N)	Mean	Std. Deviation	F	p - value	Significance
Autopolymerized Acrylic Resin	10	5.987	0.522	10.563	<0.001	
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	10	6.098	0.722			Significant
Heat Cured Denture Base Resins	10	7.001	0.288			

(p ≤ 0.05 – Significant, CI = 95 %)

One-way ANOVA was followed by Post Hoc Tukey's Test (Table-4B) and it was found that there was no statistically significant difference between the mean tensile strength of autopolymerized acrylic resin and postpolymerized microwave exposed autopolymerized acrylic resin (p=1.000).

Table-4B: Post Hoc Tukey Test

Study Groups	Autopolymerized Acrylic Resin Samples	Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	Heat Cured Denture Base Resin Samples
Autopolymerized Acrylic Resin Samples	-	1.00	0.001*
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	1.00	-	0.003*

* The mean difference is significant at the 0.05 level.

But a statistically significant difference was found between mean tensile strength of autopolymerized acrylic resin and heat-cured denture base resins (p=0.001).

Similarly, there was a statistically significant difference was also found between the mean tensile strength of postpolymerized microwave exposed autopolymerized acrylic resin and heat-cured denture base resins (p=0.003).

ROCKWELL HARDNESS NUMBER

Table-5A Shows comparison of mean Rockwell Hardness Number of autopolymerized, postpolymerized microwave exposed autopolymerized and heat-cured denture base resins.

Table-5A: Comparison of Mean Rockwell Hardness Number of autopolymerized, postpolymerized microwave exposed autopolymerized and heat cured denture base resins (One – Way ANOVA)

Study Samples	Samples N	Mean	Std. Deviation	F	p - value	Significance
Autopolymerized Acrylic Resin	10	86.000	1.763	19.896	<0.001	
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	10	82.200	3.155			Significant
Heat Cured Denture Base Resins	10	89.000	2.108			

($p \leq 0.05$ – Significant, CI = 95 %)

Analysis of Variance (One-way ANOVA) was applied to determine the comparison between three groups. A statistically significant difference was found (F = 19.896, p<0.001) in the mean Rockwell Hardness Number between the various testing groups.

One-way ANOVA was followed by Post Hoc Tukey's Test (Table-5B) and it was found that there was a statistically significant difference between mean Rockwell Hardness Number of autopolymerized acrylic resin and postpolymerized microwave exposed autopolymerized acrylic resin (p=0.005). A statistically significant difference was also found between mean Rockwell Hardness Number of postpolymerized microwave exposed autopolymerized acrylic resin and heat-cured denture base resins (p=0.001). Similarly, there was statistically significant difference was found between mean Rockwell Hardness Number of autopolymerized acrylic resin and heat-cured denture base resins (p=0.03).

Table-5B: Post Hoc Tukey Test

Study Groups	Autopolymerized Acrylic Resin Samples	Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	Heat Cured Denture Base Resin Samples
Autopolymerized Acrylic Resin Samples	-	0.005*	0.030*
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	0.005*	-	0.001*

* The mean difference is significant at the 0.05 level.

DIMENSIONAL ACCURACY

Table-6 Shows comparison of mean linear dimensional change between autopolymerized and postpolymerized microwave exposed autopolymerized denture base resins.

Table-6: Comparison of Mean Dimensional Change between autopolymerized and postpolymerized microwave exposed autopolymerized denture base resins (One – Way ANOVA)

Study Samples	Samples N	Mean	Std. Deviation	p - value	Significance
Autopolymerized Acrylic Resin	10	50.00		0.051	
Postpolymerized Microwave Exposed Autopolymerized Acrylic Resin	10	49.9270	.09956		Not Significant

($p \leq 0.05$ – Significant, CI = 95 %)

Analysis of Variance (One-way ANOVA) was applied to determine the comparison between mean dimensional changes of two groups. There was no statistically significant difference in the mean dimensional change between the autopolymerized and postpolymerized microwave exposed autopolymerized denture base resins (p=0.051).

DISCUSSION

The use of acrylic resins in dentistry involves a large range of applications. Therefore, the improvement of its physical and mechanical properties becomes necessary. Particularly, the thermo-activated, polymethylmethacrylate-based acrylic resin has become the material of choice for total or partial denture base construction, since it is dimensionally stable, cheap and possesses superior properties [7]. Autopolymerizing acrylic resin possesses lower strength than heat-cured acrylic resins. This is due to the fact that there is a higher residual monomer in autopolymerizing acrylic resins than in heat-cured acrylic resins [8]. Many different processing techniques have been proposed to improve and simplify the polymerization technique. Among them, microwave energy has been with the advantage of reduced time for curing requires a smaller time to obtain the plastic phase and the achievement of a prosthetic material with improved properties [9, 10]. Various authors have proposed that the microwave postpolymerization of autopolymerized acrylic resin improves the physical and mechanical properties and are comparable to the heat-cured resins [1, 9, 11-15].

Impact Strength

Based on the present methodology, the impact strength of autopolymerizing acrylic resin could be improved by the microwave post-polymerization treatment. The mean value of impact strength was highest for the heat-cured resin followed by postpolymerized microwave exposed autopolymerized and autopolymerized acrylic resin respectively. These findings are consistent with previous studies that found statistically higher impact strength for postpolymerized microwave acrylic resins than to autopolymerized acrylic resins [2, 15-17].

On the other hand, Memon *et al.*, [2] found that impact and flexural strength of microwave polymerized injection molded, offered no advantage over the existing heat and microwave polymerized PMMA based denture base polymers.

Tensile Strength

The tensile strength is determined by subjecting a rod, wire, or dumbbell shaped specimen to tensile loading4. The tensile strength testing conducted in this study showed that the values are maximum for the heat-cured denture base resin followed by postpolymerized microwave exposed autopolymerized and autopolymerized acrylic resin respectively.

The results of the present study were in agreement with Brouer and Dogan A *et al.*, [18] who found that the longer curing times improved the tensile strength of heat- cured acrylic resins and decreased the level of residual monomer.

Hardness

Hardness refers to the resistance to indentation4. The results of the present study demonstrated that there was a significant difference in the mean Rockwell hardness number of the three groups ($p<0.001$). Rockwell hardness testing in this study depicted the higher values for heat-cured resin (89) followed by autopolymerized (86) and postpolymerized microwave exposed autopolymerized acrylic resin (82.2) respectively.

This was in accordance with the studies of Stafford and Hugget [2] that showed that self-cured resins were the softest and the dough formed heat-cured acrylic resins were the hardest of all. In the present study, hardness was decreased of postpolymerized microwave exposed autopolymerized acrylic resin as compared to an autopolymerized acrylic resin, but the difference was seen only in four samples out of ten. The decrease in hardness observed in postpolymerized microwave exposed autopolymerized acrylic resin specimens were likely due to the disarrangement of the resin polymeric chains, under the action of microwave energy [17]. This result was in accordance with Cosnani RL [17] who found that the hardness of the autopolymerized acrylic resin specimens decreased after microwave processing. Reitz PV [12] compared the hardness and transverse strength of conventional water bath polymerized acrylic resin and microwave processed acrylic resins. They resulted that there were no significant differences found between the two groups. The results obtained in the present study were not in accordance with some authors who reported that microwaveable resins displayed greater stiffness and greater surface hardness than other denture base resins [3]. Whereas some have reported that average hardness values for the acrylic resins cured by microwave technique were at least equal to that of the conventional technique [6].

Dimensional Accuracy

The present study compared the dimensional accuracy between the autopolymerized and postpolymerized acrylic resins. Dimensional accuracy is an important requirement of many dental materials [19]. The mean dimensional change was found to be 49.9370 mm between two groups. There was no statistically significant difference in the mean linear dimensional change between the autopolymerized and postpolymerized microwave exposed autopolymerized denture base resins ($p=0.051$). These results showed accordance with some authors who reported that the microwave processing of denture base resins had equal or better dimensional accuracy than conventional heat-cured resins [20, 21]. Whereas Yadav NS [22] reported that there was slightly better accuracy of microwave processed acrylic resins than the heat-cured resins. But the results of dimensional accuracy in the present study were not in the agreement with some authors [2, 8].

CONCLUSION

Heat-cured acrylic resin exhibited the maximum values for Impact strength, Compressive Strength, Tensile Strength, Hardness and Dimensional Accuracy and Impact Strength of autopolymerized acylic resin improved after microwave postpolymerization treatment. Whereas, Hardness is decreased and Dimensional accuracy remained unaffected after the microwave postpolymerization treatment of autopolymerized acrylic resin.

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