COMPARATIVE STUDY OF THE MECHANICAL PROPERTIES OF ACRYLIC RESIN COPOLYMERS

AYŞEGÜL KÖROĞLU*, ONUR ŞAHİN*, DOĞU ÖMÜR DEDE^, BAKİ HAZER+

*Department of Prosthodontics, Faculty of Dentistry, Bülent Ecevit University, Zonguldak, Turkey.

^Department of Prosthodontics, Faculty of Dentistry, Ordu University, Ordu, Turkey.

+Department of Chemistry, Faculty of Arts and Sciences, Bülent Ecevit University, Zonguldak, Turkey.

INTRODUCTION

Polymethyl methacrylate (PMMA) is the most widely used material in the construction of complete dentures. Despite the advantages of convenient operation features, ease of processing, adherenece to oral tissues, stability and aesthetic superiority, it is far from providing all the necessary mechanical requirements for a prosthesis. It is known that, by adding varying amounts of different monomers, the copolymerization mechanism promotes the mechanical properties and chemical structure of PMMA. But in the literature there is a few studies about this subject. The aim of this study was to evaluate some mechanical properties of PMMA denture base resins polymerized by copolymerization mechanism.

Table 1: Polymethyl methacrylate (PMMA) resins used in the study.

Acrylic Resin	Code	Polymerization type	Manufacturer
Meliodent	HPAR	Conventional heat-polymerized	Meliodent, Bayer Dental, Newbury, Berkshire, UK
Acron MC	MPAR	Microwave-polymerized	Acron MC, GC Dental, Tokyo, Japan

Table 2: Monomers used in the study.

Monomer	Code	Manufacturer
Isobutyl methacrylate	IBM	Sigma -Aldrich Co. Ltd., Poole, Dorset, England
Butyl methacrylate	BM	Sigma -Aldrich Co. Ltd., Poole, Dorset, England
2-Hydroxyethyl methacrylate	HEMA	Sigma -Aldrich Co. Ltd., Poole, Dorset, England
PSS-Methacryl substituted	POSS	Sigma -Aldrich Co. Ltd., Poole, Dorset, England

MATERIALS AND METHODS

Two acrylic resins were used in the study; (1) conventional heat polymerized resin (Meliodent, Bayer Dental, Newbury, Berkshire, UK) and (2) microwave-polymerized resin (Acron MC, GC Dental, Tokyo, Japan) (Table 1). Four different monomers were ; (1) Isobutyl methacrylate (IBM), (2) Butyl methacrylate (BM), (3) 2-Hydroxyethyl methacrylate (HEMA) and (4) PSS-Methacryl substituted (POSS) (Table 2), added to monomers of conventional and microwave polymerized resin contents of 2%,5% and 10% by volume. Five specimens from each group were prepared for the mechanical tests. Stainless steel molds with dimensions of 65x10x2.5 mm for transverse strength test and 50x6x4 mm for impact strength test were prepared to mold specimens from the resins. The mixed powder -to -liquid ratio was 35g:14 mL for Meliodent resin and 100g:43 mLfor Acron MC resin. Meliodent specimens were prepared in conventional metal denture flasks and cured for 30 min after boiling. The specimens of Acron MC were prepared in fiber-reinforced plastic flasks and microwave irradiated for 3 min at 500 W. All specimen groups were bench-cooled before deflasking. All of the specimens were wet-ground with 200-, 400– and 600-grit waterproof silicone carbide paper with an automatic polishing machine (Grin PO 2V, Grinder-Polisher, Metkon A.Ş., Bursa, Turkey). A Lloyd universal testing machine (Lloyd Instruments, LRX, Fareham Hant, UK) with a crosshead speed of 5 mm/min was used for transverse strength and elastic modulus evaluation. The impact test was carried out with Charpy-type impact tester (Coesfeld, Pendulum Impact Tester, Dortmund, Germany). The mean values and standard deviations were calculated for all groups of specimens. Three -way ANOVA and Tukey HSD tests were applied for the statistical studies.

Table 3-5: Three-way ANOVA results for comparision of transverse strength, elastic modulus and impact strength values, respectively.

Table 3 : Tests of Between-Subjects' Effects

DependentVariable:Transvers_Strength						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial EtaSquared
Corrected Model	213079,307[a]	25	8523,172	23,686	,000	,851
Intercept	2696716,465	1	2696716,465	7,494E3	,000	,986
Resin material (A)	155408,081	1	155408,081	431,880	,000	,806
Monomer type (B)	8802,776	3	2934,259	8,154	,000	,190
Monomer ratio (C)	2898,540	2	1449,270	4,028	,021	,072
AxB	2121,823	3	707,274	1,966	,124	,054
AxC	9423,371	2	4711,685	13,094	,000	,201
BxC	9318,681	6	1553,114	4,316	,001	,199
AxBxC	1947,393	6	324,565	,902	,497	,049
Error	37423,471	104	359,841			
Total	3461360,158	130				
Corrected Total	250502,777	129				

a. R Squared = ,851 (Adjusted R Squared = ,815)

Table 4: Tests of Between-Subjects' Effects

DependentVariable:Elastic_Modulus						
Source	Type III Sum of Squares	df	MeanSquare	F	Sig.	PartialEtaSquared
Corrected Model	115,186[a]	25	4,607	25,197	,000	,858
Intercept	804,288	1	804,288	4,398E3	,000	,977
Resin material (A)	72,115	1	72,115	394,374	,000	,791
Monomer type (B)	7,581	3	2,527	13,819	,000	,285
Monomer ratio (C)	2,266	2	1,133	6,196	,003	,106
AxB	6,772	3	2,257	12,344	,000	,263
AxC	2,243	2	1,121	6,133	,003	,105
BxC	2,119	6	,353	1,932	,082	,100
AxBxC	1,830	6	,305	1,668	,136	,088
Error	19,017	104	,183			
Total	1097,574	130				
Corrected Total	134,203	129				

a. R Squared = ,858 (Adjusted R Squared = ,824)

Table 5: Tests of Between-Subjects' Effects

DependentVariable:Impact_Strength						
Source	Type III Sum of Squares	df	MeanSquare	F	Sig.	PartialEtaSquared
Corrected Model	462,377[a]	25	18,495	9,705	,000	,700
Intercept	14031,528	1	14031,528	7,363E3	,000	,986
Resin_material (A)	206,521	1	206,521	108,365	,000	,510
Monomer type (B)	63,058	3	21,019	11,029	,000	,241
Monomer ratio (C)	14,281	2	7,140	3,747	,027	,067
AxB	36,447	3	12,149	6,375	,001	,155
AxC	4,086	2	2,043	1,072	,346	,020
BxC	32,769	6	5,461	2,866	,013	,142
AxBxC	42,793	6	7,132	3,742	,002	,178
Error	198,202	104	1,906			
Total	16529,927	130				
Corrected Total	660,580	129				

a. R Squared = ,700 (Adjusted R Squared = ,628)

Table 6: Mean and SD of transverse strength, elastic modulus and impact strength values for test groups. *Results of Tukey post-hoc comparisions were shown as superscripts and having same letters are not significantly different.

Test Groups	Transverse Strength (MPa)	Elastic Modulus (GPa)	Impact Strength (kJ/m^2)
%100 HPAR (CONTROL)	94.24±3.11^{a}	1.72±0.19^{a}	13.05±1.768^{fg}
%2 IBM+%98 HPAR	115.66±7.77^{ab}	1.72±0.16^{a}	13.02±2.05^{c-g}
%5 IBM+%95 HPAR	120.44±8.10^{a-d}	1.71±0.40^{a}	13.64±1.33^{fg}
%10 IBM+%90 HPAR	162.98±10.30^{d-g}	2.49±0.27^{a-d}	14.71±0.55^{g}
%2 HEMA+%98 HPAR	109.08±10.40^{ab}	1.72±0.24^{a}	12.80±1.74^{d-g}
%5 HEMA+%95 HPAR	117.77±6.66^{a-d}	1.89±0.12^{ab}	13.27±1.31^{fg}
%10 HEMA+%90 HPAR	148.38±8.60^{b-f}	2.49±0.29^{a-d}	12.29±1.17^{c-g}
%2 BM+%98 HPAR	115.81±8.69^{ab}	1.71±0.28^{a}	13.05±2.00^{fg}
%5 BM+%95 HPAR	123.54±8.13^{a-d}	1.90±0.51^{ab}	12.97±3.01^{c-g}
%10 BM+%90 HPAR	129.16±8.72^{a-e}	2.16±0.51^{a-c}	11.27±1.69^{b-f}
%2 POSS+% 98 HPAR	100.05±10.24^{a}	1.61±0.29^{a}	11.80±0.90^{b-g}
%5 POSS+ %95 HPAR	114.07±11.97^{ab}	1.63±0.33^{a}	9.15±0.67^{a-c}
%10 POSS+%90 HPAR	116.96±7.72^{a-c}	1.78±0.14^{a}	10.77±1.39^{b-f}
%100 MPAR (CONTROL)	178.29±12.73^{f-i}	2.85±0.40^{b-e}	11.09±0.86^{b-f}
%2 IBM+%98 MPAR	210.48±14.63^{hi}	4.20±0.68^{h}	8.90±1.24^{ab}
%5 IBM+%95 MPAR	196.89±13.83^{g-i}	3.91±0.46^{f-h}	8.70±0.66^{ab}
%10 IBM+%90 MPAR	204.25±8.76^{g-i}	3.67±0.50^{e-h}	9.74±0.50^{a-c}
%2 HEMA+%98 MPAR	197.17±10.69^{g-i}	3.78±0.45^{e-h}	11.69±1.26^{b-g}
%5 HEMA+%95 MPAR	214.16±13.17^{hi}	3.96±0.57^{gh}	9.62±0.57^{a-d}
%10 HEMA+%90 MPAR	210.43±13.68^{hi}	4.17±0.40^{h}	9.45±0.80^{a-c}
%2 BM+%98 MPAR	188.54±12.06^{f-i}	2.46±0.61^{a-d}	11.24±1.23^{b-f}
%5 BM+%95 MPAR	187.99±13.64^{f-i}	3.03±0.66^{c-g}	9.38±1.22^{a-c}
%10 BM+%90 MPAR	170.06±6.99^{e-h}	2.93±0.35^{c-f}	8.90±1.12^{ab}
%2 POSS+% 98 MPAR	179.09±12.25^{f-i}	3.38±0.45^{d-h}	8.79±1.76^{ab}
%5 POSS+ %95 MPAR	219.42±13.75^{i}	4.26±0.31^{h}	10.43±0.87^{a-f}
%10 POSS+%90 MPAR	161.196±11.45^{e-g}	3.54±0.62^{e-h}	7.43±0.99^{a}

RESULTS

According to the three-way ANOVA results of transverse strength, elastic modulus and impact strength, resin material type, monomer type and monomer ratio were statistically significant ($p<.05$) For transverse strength, the interaction between resin material and monomer ratio and the interaction between monomer type and monomer ratio were statistically significant ($p<.05$) (Table 3). In terms of elastic modulus the interaction between resin material and monomer type and also the interaction between resin material and monomer ratio were statistically significant ($p<.05$) (Table 4). For impact strength the interaction between resin material and monomer type and the interaction between monomer type and monomer ratio were statistically significant ($p<.05$) (Table 5). The mean transverse strength, elastic modulus and impact strength values and standard deviations (SD) for all test groups are shown in Table 6. The Tukey HSD results are also shown in these tables as small letters. Although in all study groups the copolimerization mechanism increased the value of transverse strength, only the 10% IBM and 10 % HEMA conventional heat polymerized resin groups showed statistically significant difference ($p<.05$). For elastic modulus values, in conventional heat polymerized resin group there was no statistically significant difference between the control group and the resin groups ($p>.05$). But in microwave polymerized resin group there was a statistically significant difference between control group and 2% IBM, 5% IBM, 5% HEMA and 5% POSS resin groups ($p<.05$). In terms of impact strength, except 5% POSS conventional heat and 10% POSS microwave polymerized resin group there was no significant difference between the control group and the resin groups ($p>.05$).

CONCLUSION

In previous studies, copolymerization mechanism is proposed for the improvement of the mechanical properties of the denture base acrylic resins. In the present study, copolymerization process was effective in the transverse and impact strength of some resin groups. Therefore, there is a need for further studies about the ideal monomer/polymer ratios.