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Effects of Addition of Aluminum Oxide on Flexural Strength and Hardness of Acrylic Resins

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Abstract:
Purpose: *Acrylic dentures frequently fracture during service due totheir poor strength characteristics. The aim of this study was to evaluate the effects of adding 5%, 10% and 15% aluminum oxide powder on the flexural strength, surface hardness of a conventional heat-polymerized acrylic resin.*
Materials and methods: *One of the commonly used conventional heat cure denture base resin (DPI) and high impact heat cure denture base resin(lucitone) with incorporation of three different percentage of aluminum oxide concentration was studied in 4 groups of 10 samples each.*
A standard mould measuring 65 x 10 x 3mm3 (ISO 1567 standard) was obtained for the fabrication of 40 specimens that were divided into 4groups; group-A was unmodified denture base resin (Control group), group-B, group-C and group-D were modified denture base resin with 5%, 10%and 15% by wt. aluminum oxide powder respectively.All specimens were stored in distilled water at 37º C for 7 days. The flexural strength of thespecimens was measured using 3-point bending test in a Universal Testing Machine.Hardness testing was conducted using shore hardness tester.
Conclusion: *Reinforcement of the conventional heat-cured acrylic resin(DPI) and high impact heat cured acrylic resin(LUCITONE) with 15% by wt.% Aluminum oxide powder significantly increased its flexural strength and hardness with no adverse effects.*
Keywords: *Conventional heat cure denture base resins; flexural strength; aluminum oxide powder,hardness.*

I. Introduction

One of the most widely used materials in prosthetic dentistryis polymethyl methacrylate (PMMA). Since its introduction todentistry, it has been successfully used for denture basesbecause of its ease of processing, low cost, light weight, andcolor-matching ability(1, 2). However, acrylic resin denture basematerials have poor strength(3, 4).

Many attempts have been made to enhance the strengthof acrylic denture bases including the addition of metalwires and cast metal plates(5-7).The primary problem withusing metal wire is poor adhesion between the wire andresin(7).Although metal plates increase thestrength, they may be expensive and prone tocorrosion.

Mechanical reinforcement of acrylics has alsobeen attempted through the inclusion of fibers and metalinserts(5, 8).Although the inclusion of the fibersproduced encouraging results, this method has variousproblems including tissue irritation, increased productiontime, difficulties in handling, the need for precise orientation,and placement or bonding of the fibers within theresin(1, 9, 10).

In the case of metal inserts, failure due to stressconcentration around the embedded inserts has beenreported. Although it has been reported that untreated aluminumoxide (Al2O3) powder develops physical properties of highimpactacrylic resin(11-13),there have been no investigationsregarding the effect of Al2O3 powder on the mechanicalproperties of a conventional heat-cured acrylic resin.Therefore, we evaluated the effects of Al2O3 at threedifferent concentrations on the flexural strength (FS),surface hardness of a conventionalheat-cured acrylic resin and high impact heat-cured acrylic resin.

II. Materials and Methods

A custom tray made of self cure acrylicmaterial suitable for the stainless steel mold was fabricated. With thepolyvinylsiloxane impression material,an impression of this mold was made and master cast was poured with improved dental stonei.e. die stone (Kalrock). Modeling wax was placed in each of the compartment. Master cast was invested in the dental flask using dental stone following manufacturer's instructions. was carried out and mold was allowed to cool. A standard moldmeasuring 65 x 10 x 3mm3 (ISO 1567 standard) was obtained for the fabrication of 40 specimens which were divided into 4 groups of 10 each.

Fig A: stainless steel mold

Fig B: master cast

About 40 specimens of DPI heat cure resin and 40 specimens of LUCITONE heat cure resin were divided into 4 groups each:

Group-A: Unmodified heat cure denture base resin(Control group).
Group-B: Modified heat cure denture base resin withaddition of 5% by wt. aluminium oxide powder.
Group-C: Modified heat cure denture base resin withaddition of 10% by wt. aluminium oxide powder.
Group-D: Modified heat cure denture base resin withaddition of 15% by wt. aluminium oxide powder.

Fig C: Lucitone heat cure material

Fig D: DPI heat cure material

Three concentrations(5%,10% and 15%) of aluminum oxide powder(5-22 microns) were mixed with polymer.As per Ellakwa et al(12)andSehajpal et al(2),for an even distribution of filler withinthe polymer matrix, Aluminum oxide powderwasmixed with resinpowder and liquid monomer. The oxide powder andacrylic powder were thoroughly mixed using a mortar andpestle for initial mixing and blending, followed by handtumbling in a plastic jar until a uniform color is achieved.When the mix had reached doughstage, it was packed into the molds and the flask was kept inbench press unit for bench curing for 30mins and curing was done according to manufacturer'sinstructions.Specimens were stored indistilled water at 37º C for 7 days before test.

The flexural strength of the specimens were tested in universal testing machine.Load was applied at the center of the specimen at a cross head speed of 5mm/minute,until it fractured.

Fig E: Universal testing machine

For hardness testing, to determine Vickers values, a load of 30 g was applied for 30seconds to specimens using a digital hardness tester. Eachspecimen was subjected to three indentations (one at thecenter and two at the border), and the average value wascalculated for each group.

Fig F: Shore hardness tester

The values obtained were subjected to statistical analysisusing one way ANOVA followed by post hoc Tukey's test formultiple group comparison and paired 't' test for intra groupcomparisons.

III. Results

The mean flexural strength of DPI heat cure resin group A is 78.2 MPa,group B is 79.4 MPa, group C is 82.3 and group D is 82.37.The mean flexural strength of LUCITONE heat cure resin:group A is 75.5 MPa, group B is 80.8 MPa,group C is 82.8 MPa and group D is 83.4 MPa.Lucitone added with 15% aluminum oxide by wt. is found to have highest flexural strength.

Hardness of DPI heat cure resin group A is 65.5 MPa,group B is 73.3 MPa,group C is 85.8 MPa,group D is 91.1 MPa. The hardness of LUCITONE heat cure resin group A is 66.6 MPa,group B is 71.8 MPa,group C is 81.9 MPa,group D is 97.3 MPa.Hardness is also highest with lucitone added with 15%aluminum oxide powder.

Table 1 shows the flexural strength values of the groups.Table 2 shows the graphical representation of the flexural strength values.Table 3 shows the hardness values of the groups.Table 4 shows the graphical representation of the hardness values.Table 5 shows the comparison between DPI and LUCITONE heat cure resin materials.Table 6 shows the graphical representation of comparison between DPI and LUCITONE heat cure materials.

Table 1: Flexural strength values of the groups

Groups	*n*	*Mean*	SD	F-Value	P-Value	Decision
CONTROL DPI	9	78.22222	3.374455	16.216	0.000	Significant
AL2O3 5%+DPI	9	79.47778	2.133529			
AL203 10%+DPI	9	82.3	0.947365			
AL2O 15%+DPI	9	82.37778	1.428966			
CONTROL+LUCITONE	9	75.58889	2.731503			
AL203 5%+LUCITONE	9	80.85556	2.010666			
AL2O3 10%+ LUCITONE	9	82.85556	1.048941			
AL2O3 15%+ LUCITONE	9	83.45556	1.048941			

Table 2: Graphical representation of the flexural strength values

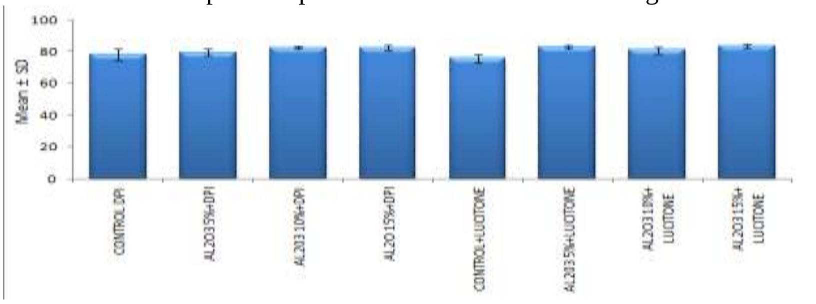


Table 3: Hardness values of different groups

Groups	*n*	*Average*	SD	F-Value	P-Value	Decision
CONTROL DPI	9	65.05556	8.919236	17.695	0.000	Significant
AL2O3 5% +DPI	9	73.31111	3.917092			
AL2O3 10%+DPI	9	85.85556	11.75001			
AL2O3 15%+DPI	9	91.17778	13.61716			
CONTROL LUCITONE	9	66.63333	8.039745			
AL2O3 5%+LUCITONE	9	71.81111	4.929869			
AL2O3 10%+LUCITONE	9	81.91111	4.868892			
AL2O3 15%+LUCITONE	9	97.36667	5.84658			

Table 4: Graphical representation of hardness values

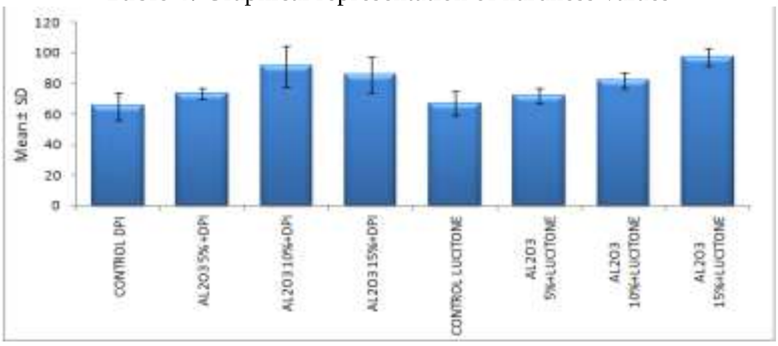
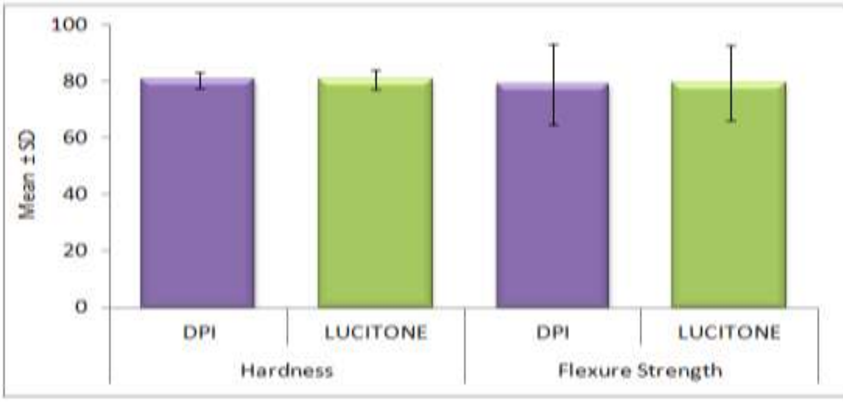


Table 5: Comparison between Lucitone and DPI heat cure materials

		N	Mean	SD	T-Value	P-Value	Decision
Hardness	DPI	36	80.5944	2.7656	-0.125	0.9011	Not Significant
	LUCITONE	36	80.6889	3.6060			
Flexure Strength	DPI	36	78.85	14.29	-0.179	0.8585	Not Significant
	LUCITONE	36	79.43	13.23			

Table 6: Graphical representation to compare Lucitone and DPI heat cure materials



IV. Discussion

The ultimate flexural strength of a material reflects its potentialto resist catastrophic failure under a flexural load. As a foundation, the acrylic resinmaterials should exhibit a high proportional limit to resist plasticdeformation and also exhibit fatigue resistance to endure

repeated masticatory loads(14-16).The denture base in a removable prosthesis with highflexural strength, flexural modulus, and a large yield pointdistance would help to resist torsional forces in function, leading to a longer clinical service life for the prosthesis. Carbon fibers have been added to the resin matrix andhave proved to be successful in increasing the strength of the

denture base(8). Despite producing successful reinforcement, theblack colour the fibers impart to the resin can be unacceptable tosome denture wearers.

Mullarky RH (17)studied the reinforcement of acrylic resin with aramid fibers. He was successful in enhancing the fatigue resistance of thearamid fiber reinforced acrylic resin denture base material.The yellow appearance of the fibers was difficultto mask within the denture, necessitating thick layers of acrylicresin that added significantly to the bulk of the denture.

MahrooVojdani, RafatBagheri(18) conducted a study which showed that addition of2.5 wt% of untreated Al2O3 to a conventional heat-curedresin improved the mechanical properties of PMMAwithout essential additional processing steps. Therefore,the fabrication of dentures by this method is not timeconsuming,which would encourage its routine use indental laboratories due to its low cost and ease of handlingand processing.Ellakwa(12) and colleagues havereported that reinforcing high-impact acrylic resin with untreated Al2O3 powder at concentrationsof 5-20 wt% resulted in increases in both the flexural strength andthermal diffusivity of this high-impact acrylic resins.Their study also showed that the hardness increased in proportion tothe weight percentage of the Al2O3 filler. The hardnesssignificantly increased after incorporating 2.5 and 5 wt%Al2O3.

This finding is in agreement with previous investigators,who have concluded that reinforcing dentalrestorative resins and acrylic resin with ceramic particlescan produce some improvements in the surface hardness(4, 5, 19, 20).This increase in hardness may have been due to inherentcharacteristics of the Al2O3 particles. Al2O3 possesses strongionic interatomic bonding, giving rise to its desirablematerial characteristics, that is, hardness and strength(19, 21).

Aluminum oxide, commonly referred to as alumina has highhardness, excellent dielectric properties, refractoriness, and goodthermal properties make it the material of choice for a wide rangeof applications. Further more,the white colour of aluminum oxide powder is not expected to affect adversely the esthetic appearance of denture base resins.

V. Conclusion

Flexural strength of conventional high impact heatcure denture base resin (group-A) increased with addition ofincreased percentage of aluminum oxide powder. Incorporation of 5% by wt. aluminum oxide powderto heat cure denture base resin (group-B) did not producesignificant increase in flexural strength of conventional dentureresin (group-A). Incorporation of 10% (group-C) and 15% (group-D)by wt. aluminum oxide powder to heat cure denture base resin significantly increased the flexural strength of denture baseresin. Highest flexural strength was found with 15% by wt.incorporation of aluminum oxide powder to heat cure denturebase resin (group-D).

Hardness increased with addition of increased percentage of aluminum oxide powder.Lucitone added with 15% by weight aluminum oxideis found to have the highest hardness values.

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