The effect of aluminum oxide on heat polymerized acrylic resin denture base material to flexural strength and color stability

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ABSTRACT
Purpose: The purpose of this study was to determine the effect of aluminum oxide addition on heat polymerized acrylic (HPA) resin denture base to flexural strength and color stability. **Method**: This study was carried out on HPA resin samples without and with the addition of aluminum oxide with a concentration of 0.5%, 1.5%, 2.5%. A bar-shaped sample sized 65 x 10 x 3 mm was used for flexural strength testing and circular-shaped sample with a diameter of 50 mm x 1 mm (no. 80) was used for color stability testing; 24 samples for flexural strength test and 24 samples for color stability test. All samples were immersed in distilled water for 48 hours at 37˚C in an incubator. A universal testing machine was used to test flexural strength and a portable colorimeter was used for color stability testing. **Conclusion**: The addition of 0.5% aluminum oxide significantly increase the flexural strength and has good color stability.
Keywords: heat polymerized acrylic resin, aluminum oxide, flexural strength, color stability.

INTRODUCTION

Denture base is a part of denture that rests on soft tissue and does not include the artificial teeth.[1] Denture base material is divided into two groups, metal and nonmetal.[2,3] Non-metal denture base, namely resins, can be classified into two groups based on their thermal reactions, namely thermoplastics and thermosets.[4,5] Thermosets are resins which, once formed, cannot be reshaped by heating, and cannot be recycled. The examples of this resins were acrylic resins.[2-5]

Acrylic resin is the most widely used materials for the manufacture of dentures.[5] Heat polymerized acrylic (HPA) resins were the denture base materials which bear the polymerization process by applying heat. This material has many advantages such as easy to process and polish, aesthetically affordable, and low toxic, but it also has low mechanical properties, resulting in frequent denture base fractures. According to ADA specification no. 12 (ISO 1567), flexural strength of the HPA resin was 65 MPa.[6] The HPA resins have good aesthetics, because of its translucent colors and they are close to gingival colors. The degree of color change was determined by a colorimeter or spectrophotometer that has a standard; if the value of ΔE is more than 3.7 then the color is unstable.[7-9]

Several studies have linked the use of reinforcing materials with the strength of HPA resin denture base and found a significant influence. The addition of reinforcing material in the form of metal oxide to HPA resin can affect the physical, mechanical and biological properties of the denture base. Metal oxide which will be added to the HPA in this study was aluminum oxide (Al_2O_3). Aluminum oxide was chosen because it is a biocompatible material, has a low density and it is lightweight.[10,11]

The purpose of this study was to determine the effect of aluminum oxide addition on HPA resin denture base to flexural strength and color stability.

METHOD

This experimental laboratory with post test only with control group design used samples of HCA resin without addition of aluminum oxide and with the addition of aluminum oxide (Beta Diamond Products) with three different concentration groups: 0.5%, 1.5% and 2.5%. The number of samples for each group is 6, so the total sample for 8 groups is 48 samples.

The size of custom made model of metal used for flexural strength tests according to ISO 1567 is (65 x 10 x 3 mm) ± 0.5 mm[12] and for color stability test according to ADA no. 80 is circular in diameter (50 x 1 mm) ± 0.5 mm (Fig. 1).[9]

This study was carried out by making samples (Fig.2), measuring flexural strength, and color stability. Samples was made through the process of making molds, filling acrylic in molds, curing, and finishing. The finishing is done by polishing and immersing the samples in distilled water at 37^{0}C for 48 hours in an incubator.

Measurement of flexural strength is carried out using the Universal Testing Machine, Tensilon AND RTF-1350 (Fig.3A). The sample is marked at both ends and the measuring area is mea-

sured and placed between the pulling plates. Before the test takes place, the instrument was first calibrated with a pointer at exactly zero. The device was then turned on, the number indicated by the measurement on the tool is recorded as an F value after the sample has fracture (MPa).

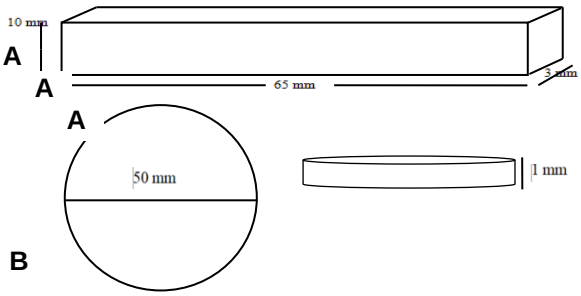


Fig.1 Size of the sample **A** of flexural strength; **B** of color stability

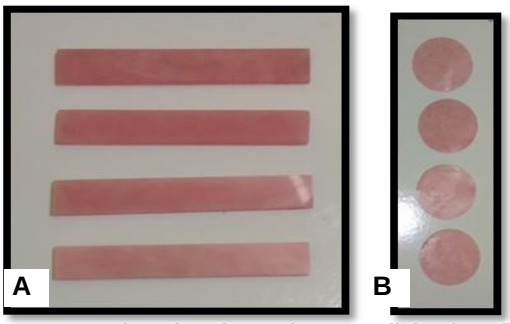


Fig 2 Samples that have been polished **A** flexural strength test; **B** color stability test

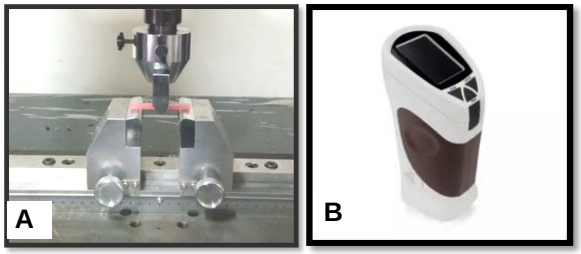


Fig 3A Flexural strength test using Universal Testing Machine; **B** portable Colorimeter CS-10

Color stability measurements were carried out by means of the color of the sample measured before and after aluminum oxide addition using Colorimeter CS-10 (Fig 3B). The colorimeter was set to measure mood and placed perpendicular to the sample surface. The instrument was held in a direction against 90^0 surface center of the sample and the test button was pressed until the machine beeps to indicate completion of the measurement and the results were displayed on the display device. The results were displayed in L*a*b format. Each reading was repeated three times by the researcher to get identical and sequential readings achieved and then averaged values were recorded.

RESULT

The mean value and standard deviation of flexural strength in this study were analyzed using univariate tests. The mean value and standard deviation of HPA resin denture base without the addition of aluminum oxide was 89.09 ± 0.12 MPa, with the addition of 0.5% aluminum oxide concentration was 102.93 ± 0.27 MPa, with the addition of 1.5% aluminum oxide concentration was 111.95 ± 0.20 MPa, with the addition of 2.5% aluminum oxide concentration was 122.03 ± 0.25 MPa (Table 1).

Table 1 Value of HPA resin denture base flexural strength without and with the addition of aluminum oxide with concentrations of 0.5%, 1.5%, and 2.5%

No	Flexural Strength (MPa)			
	Without Aluminum Oxide	Addition of Aluminum Oxide		
		0.5%	1.5%	2.5%
1	88.97*	102.55*	111.85	121.94
2	89.23	102.74	111.75	121.99
3	88.97	103.20	112.16	122.38**
4	89.07	103.25**	112.03	121.95
5	89.24**	102.81	111.74*	121.67*
6	89.06	102.97	112.18**	122.26
	$\bar{x}$ =89.09	$\bar{x}$ =102.92	$\bar{x}$ =111.95	$\bar{x}$ =122.03
	SD=0.12	SD=0.27	SD=0.20	SD=0.25

Description: * Smallest ** Biggest

Average value and standard deviation of the color stability of HPA denture base in this study were analyzed using univariate tests. The mean value and standard deviation of the color stability of HPA resin denture base without the addition of aluminum oxide was 0 ± 0.00 with the addition of 0.5% aluminum oxide was 3.28 ± 0.25, with the addition of 1.5% aluminum oxide was 7.30 ± 0.37. with the addition of 2.5% aluminum oxide was 9.37 ± 0.25 (Table 2).

The effect of aluminum oxide addition with concentrations of 0.5%, 1.5%, and 2.5% on HPA resin denture base on flexural strength and color stability in this study was analyzed using the one-way Anova-test. Previously, normality data was tested using the Saphiro-Wilk. After that,the data homogenity was performed using Levene test to find out that the data is truly homogeneous.

The one-way ANOVA test results gained significance with p = 0.0001 (p <0.05), then H_0 is rejected and Ha accepted. This means that

there was a significant influence in the addition of aluminum oxide with a concentration of 0.5%, 1,5%, and 2.5% in the heat polymerized acrylic resin denture base flexural strength. (Table 3)

Table 2 The value HPA resin denture base acrylic without and with the addition of aluminum oxide with concentrations of 0.5%, 1.5%, and 2.5%

No	Color Stability (values)			
	Without Aluminum Oxide	Addition of Aluminum Oxide		
		0.5%	1.5%	2.5%
1	0	3.15	7.14	9.34
2	0	2.84*	6.87*	9.84**
3	0	3.44	7.96**	9.14*
4	0	3.47	7.33	9.22
5	0	3.28	7.42	9.42
6	0	3.49**	7.11	9.24
	$\bar{x}$=0	$\bar{x}$=3.28	$\bar{x}$=7.30	$\bar{x}$=9.37
	SD=0	SD=0.25	SD=0.37	SD=0.25

Specification: * Smallest ** Biggest

Table 3 The effect of the addition of aluminum oxide with concentrations of 0.5%, 1.5%, and 2.5% on the HPA resin denture base flexural strength (Anova test)

Group	Flexural Strength		p
	n	$\bar{x}$ ± SD	
Without reinforcing materials	6	89.09 ± 0.12	
Aluminum 0.5%	6	102.92 ± 0.27	0.0001*
Aluminum 1.5%	6	111.95 ± 0.20	
Aluminum 2.5%	6	122.03 ± 0.25	

Note: * significant

Table 4 The effect of the addition of aluminum oxide with a concentration of 0.5%, 1.5%, and 2.5% on HPA resin denture base color stability (Anova test)

Group	Color Stability		p
	n	$\bar{x}$ ± SD	
Without reinforcement material	6	0.00 ± 0.00	
Aluminum 0.5%	6	3.28 ± 0.25	0.0001*
Aluminum 1.5%	6	7.30 ± 0.37	
Aluminum 2.5%	6	9.37 ± 0.25	

Description: * Significant

The one-way ANOVA test results gained significance with p was 0.0001; less than 0.05. This means that there was a significant influence in the addition of aluminum oxides with concentrations of 0.5%, 1.5%, and 2.5% in HPA resin denture base color stability (Table 4).

The difference in the effect of the addition of aluminum oxide with a concentration of 0.5%, 1.5%, and 2.5% on the HPA resin denture base material of the flexural strength and color stability was tested by LSD; it showed a difference in the influence of flexural strength between the test group (p was 0.0001) (Table 5). The test showed a difference in the effect of color stability between the the group (p was 0.0001) (Table 6).

DISCUSSION

Table 1 shows the flexural strength of HPA resin denture base samples with the addition of aluminum oxide with a concentration of 0.5%, 1.5%, and 2.5% were greater than the samples

Table 5 The difference in the effect of aluminum oxide addition with a concentration of 0.5%, 1.5%, and 2.5% in the HPA resin denture base flexural strength (LSD)

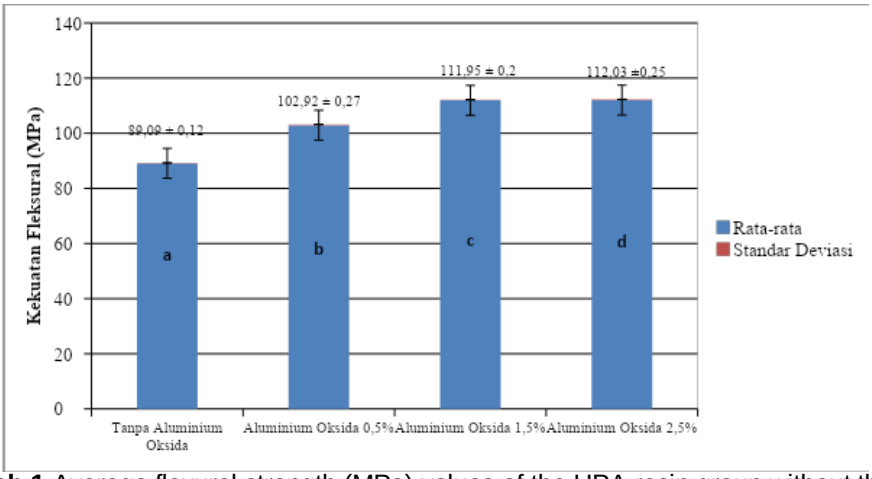
Group		Mean diference	p
Group aluminum oxide 0.5%	Aluminum oxide 1.5%	-9.02	0.0001 *
	Aluminum oxide 2.5%	-19.11	0.0001 *
Aluminum oxide group 1.5%	Aluminum oxide 0.5%	9.02	0,0001 *
	Aluminum oxide 2.5%	-10.08	0,0001 *
Aluminum oxide group 2.5%	Aluminum oxide 0.5%	19.11	0,0001 *
	Aluminum oxide 1.5%	10.08	0.0001 *

Description: * Significant

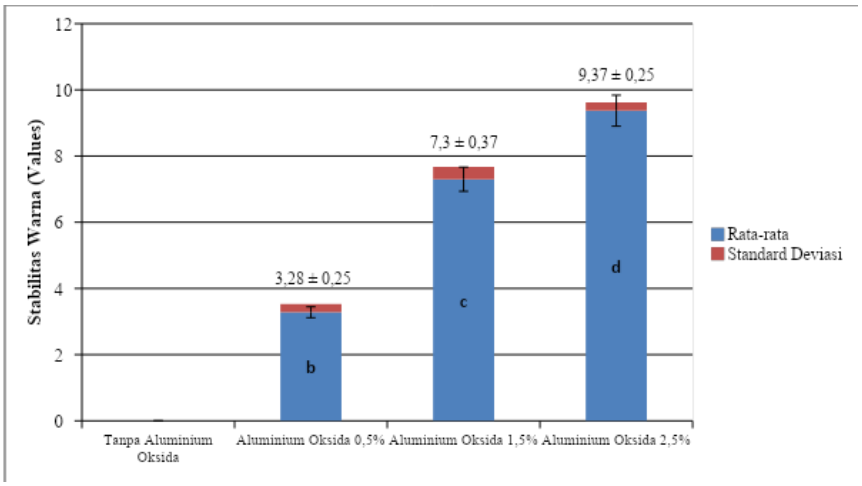
Table 6 The difference in the effect of aluminum oxide addition with a concentration of 0.5%, 1.5%, and 2.5% in the HPA resin denture base color stability (LSD)

Group		Mean diference	p
Group aluminum oxide 0.5%	Aluminum oxide 1.5%	-4.03	0.0001 *
	Aluminum oxide 2.5%	-6.09	0.0001 *
Aluminum oxide group 1.5%	Aluminum oxide 0.5%	4.03	0,0001 *
	Aluminum oxide 2.5%	-2.06	0,0001 *
Aluminum oxide group 2.5%	Aluminum oxide 0.5%	6.09	0.0001 *
	Aluminum oxide 1.5%	2.06	0.0001 *

Description: * Significant



Graph 1 Average flexural strength (MPa) values of the HPA resin group without the addition of aluminum oxide and with the addition of aluminum oxide concentration of 0.5%, 1.5%, and 2.5%; vertical lines indicate standard deviations; different letters indicate significant differences.



Graph 2 Average value of the color stability (values) of HPA resin without the addition of aluminum oxide and with the addition of aluminum oxide concentration of 0.5%, 1.5%, and 2.5%; vertical lines indicate standard deviations; different letters indicate significant differences.

without aluminum oxide addition. According to ADA specifications no. 12 the flexural strength value of HPA resin was 65 MPa. The flexural strength increase with increasing aluminium oxide concentration. This study was in line with Pentapati et al who add aluminum oxide at concentrations of 5%, 10%, and 15% in HPS resins. The 15% aluminum oxide concentration can increase the flexural strength without side effects. The greater concentration, the greater flexural strength is also obtained.[13] Increasing value of flexural strength in the sample with the addition of aluminum oxide can occur due to various factors including good adhesion between the polymer matrix of acrylic resin and aluminum oxide.[14] This good adhesion occured because aluminum oxide can be chemically bonded with the -COOR group of HPA resin polymer. Aluminum oxide will form crosslinking with HPA resin. The formation of crosslinking will increase the denture base resistance to fractures. This formation of crosslinking will also cause an increase in the surface shift strength between aluminum oxide and the polymer matrix, there by reducing the cracking of material and increase the flexural.[15]

Table 2 shows that the HPA resin denture base sample which was added aluminum oxide with a concentration of 0.5%, 1.5%, and 2.5% experienced a change in color when compared to the HPA resin sample which no aluminum oxide is added. Discoloration of the sample occurs because a white aluminum oxide powder is mixed with a HPA resin powder which causes a change in color. The higher concentration of alu-

minum oxide mixed in the HPA resin powder, the whiter the base material produced. Color stability has a standard if the ΔE value is more than 3.7, so the color is unstable or not aesthetic, so it is not recommended to be applied to the patient's mouth. And based on this study the value of ΔE is relatively stable on the addition of aluminum oxide with a concentration of 0.5%. The results of this study are in line with research from Sahin, et al. They added nano zirconium dioxide with a concentration of 1% to HPA resins. In his study, it was found that the value of ΔE was less than 3.7 for the color stability test so that it was classified as stable and within acceptable clinical limits.[16]

Based on the data in Table 3 from the results of the one-way Anova test, there was a significant influence in the addition of aluminum oxide to the HPA resin denture base flexural strength p was 0.0001; less than 0.05. The results of this study are similar to the results of research conducted by Pentapati, et al who use aluminum oxide with concentrations of 5%, 10%, and 15%. His research states that the addition of aluminum oxide with concentrations of 5%, 10%, and 15% has a significance value of p was 0.0001. It shows that the addition of aluminum oxide with a concentration of 5%, 10%, and 15% to the HPA resin causes an increase in flexural strength.[13]

Based on the data in Table 4 from the results of the one-way Anova test, there is a significant influence in the addition of aluminum oxide to the HPA resin denture base material on color stability p was 0.0001; less than<0.05). The results of this study are similar to Sahin, et al. They added nano zirconium dioxide with a concentration of 1% to the HPA resin which can change color, but not significantly. The addition of nano zirconium dioxide with a concentration of 1% to the color stability has a significant value of p was 0.713.[16]

Statistical analysis based on table 5 shows that there is a significant difference to the addition of aluminum oxide with a concentration of 0.5%, 1.5%, 2.5% against the flexural strength of HPA resin denture base between the tested groups.The aluminum oxide addition group with a concentration of 2.5% showed a higher flexural strength than the aluminum oxide addition group with a concentration of 1.5% and 0.5%. This occured because the addition of aluminum oxide to HPA resin with different concentrations of 0.5%, 1.5%, and 2.5% will affect the amount of crosslinking formed. The more concentrations of aluminum oxide added to HPA resin will cause more crosslinking to form and the better the flexural strength produced.[14,15]

The results of statistical analysis based on table 6 show that there is a significant difference in the effect of adding aluminum oxide with concentrations of 0.5%, 1.5%, and 2.5% on the color stability of HPA resin denture base between the tested groups. The aluminum oxide addition group with a concentration of 2.5% showed a higher increase in color stability compared to the aluminum oxide addition group with a concentration of 1.5% and 0.5%. This occurred because the white aluminum oxide powder is mixed with a HPA resin powder which causes a change in color. The higher the concentration of aluminum oxide mixed in the HPA resin powder, the whiter the base material produced.[16]

The flexural strength and color stability increased after the addition of aluminum oxide. The addition of aluminum oxide groups with concentrations of 0.5%, 1.5%, and 2.5% significantly increased the flexural strength of denture base. The addition of aluminum oxide group with a concentration of 0.5%, 1.5%, and 2.5% also significantly affects the color stability, and which still has good color stability is also still within the acceptable clinical limit is the aluminum oxide addition group with a concentration of 0.5%, so the addition of aluminum oxide with 0,5% concentration increase flexural strength and still have good color stability. It can be concluded that aluminum oxide has been proven to be used to increase flexural strength with good color stability on a HPA resin denture base. If it is associated clinically it will withstand excessive mastication loads, can be used for a longer time, and for colors that are aesthetic.

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