The effect of nanoparticles TiO_2 on the flexural strength of acrylic resin denture plate

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ABSTRACT

Introduction: Acrylic resin is still the most commonly used denture base material due to its ideal properties. However, acrylic resin denture fractures are still considered a major unsolved problem thus the addition of nanoparticles as filler was performed to increase its mechanical properties. The purpose of this study was to discovered the effect of nanoparticles TiO_2 on the flexural strength of acrylic resin denture plate. **Methods:** This study used 27 heat-cured acrylic resin specimens sized 65 x 10 x 2.5 mm. The samples were divided into three concentration groups (n = 9), the control group; 1% of nanoparticles TiO_2; and 3% of nanoparticles TiO_2. The flexural strength was tested using the Universal Testing Machine. All data were analysed using the one-way ANOVA test with 95% confidence level then continued with the Least Significant Difference (LSD) test. **Results:** There were significant flexural strength differences in different concentration of nanoparticles TiO_2. The highest flexural strength value was found in the 1% of nanoparticles TiO_2 group (106.99 ± 6.09 MPa), whilst the lowest flexural strength value was found in the 3% of nanoparticles TiO_2 group (91.64 ± 5.38 MPa). Significant flexural strength difference was found between the control group and the 1% of nanoparticles TiO_2 group, and also between the 1% of nanoparticles TiO_2 group with the 3% of nanoparticles TiO_2 group ($p < 0.05$). **Conclusion:** From this study can be concluded that concentration of 1% of nanoparticles TiO_2 was able to increase the flexural strength of acrylic resin denture plate.

Keywords: Acrylic resin, flexural strength, titanium dioxide

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INTRODUCTION

Acrylic resin is still becoming a preferable material for denture base because of the economic cost, repairable, easy manufacturing process, simple tools, and also stable & easily polished. However, acrylic resins also have several disadvantages, some of them are having a low flexural strength compared to the metal frames, low thermal conductivity, produces residual monomers, porosity potential, permeable, and easily fractures.[1,2] Previous research showed that as

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much as 68% of denture fracture occurred almost after 3 years of use, 28% occurred after 1 year, and 39% of the denture needs to be repaired after 3 years of use. Denture fracture is still becoming an unsolved problem until now.[3,4]

Several attempts were made to increase the mechanical properties of the acrylic resin such as the flexural strength. Flexural strength is a force directly related to the fracture resistance of a denture.[5] Chemical industry research nowadays are focusing on the addition of nanoparticles such as titanium dioxide (TiO_2), silicon dioxide (SiO_2), aluminium oxide (Al_2O_3), and zirconium dioxide (ZrO_2), into an acrylic resins to produce new materials which have the same mechanical properties with the nano-oxide particles, but with the flexibility of the polymer matrix.[6] Nano-oxide particles are commonly used due to the small size, strong interactions with organic polymers, non-toxic, non-biochemical reactions, with anti-fungal and anti-bacterial properties.[7] The use of titanium dioxide nanoparticles is increasing due to the advantages over other nanoparticles, which are non-toxic, inert chemical properties, economic cost, powerful antibacterial properties, corrosion resistance, and high level of hardness.[8]

Nanoparticles TiO_2 are able to fill the PMMA chain spaces thus reducing porosity by increasing the density of the acrylic resins density.[9] Silanization of the TiO^2 nanoparticles serves as a coupling agent to ensure the interfacial adhesion between the TiO_2 nanoparticles and the polymer matrix of the acrylic resin thus creates strong bonding and increases the crosslink on the acrylic resin polymer chains.[10] The purpose of this study was to discovered the effect of nanoparticles TiO_2 on the flexural strength of acrylic resin denture plate.

METHODS

This study was experimental laboratory research with as much as 27 study subjects consisted of acrylic resin plate with the size of 65 x 10 x 2.5 mm (ADA® Sp. No. 12) divided into 3 groups (n = 9). All samples were divided into 3 concentration groups, namely the control group, 1% of nanoparticles TiO_2 concentration group, and 3% of nanoparticles TiO_2 concentration group. The materials used in this research were acrylic resin (QC 20-Densply®), TiO_2 (Sigma-Aldrich®), and silane (Ultradent®-Fondaco) nanoparticles, as shown in Figure 1. The tools used in this research were digital scales and Universal Testing Machine (NW7 3LR, Pearson® Panke Equipment, London) to test the flexural strength, as shown in Figure 2.

Silanization of the TiO2 nanoparticles was then allowed to stand for 14 days at room temperature.[9] The manufacture of test plates

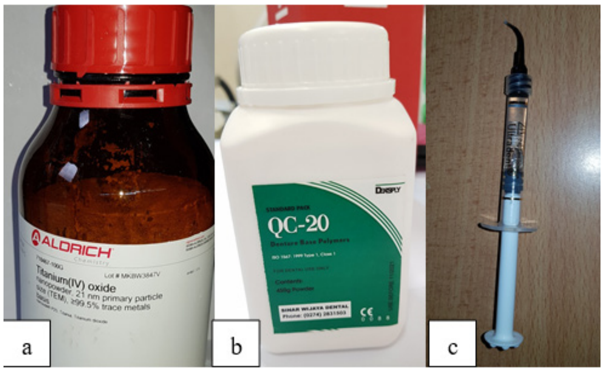

Figure 1. Research materials; a. Nanoparticles TiO_2; b. Acrylic resin; c. Silane

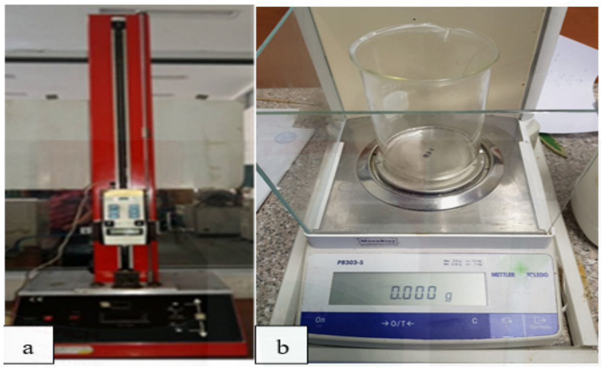

Figure 2. Research tools; a. Universal Testing Machine; b. Digital scales.

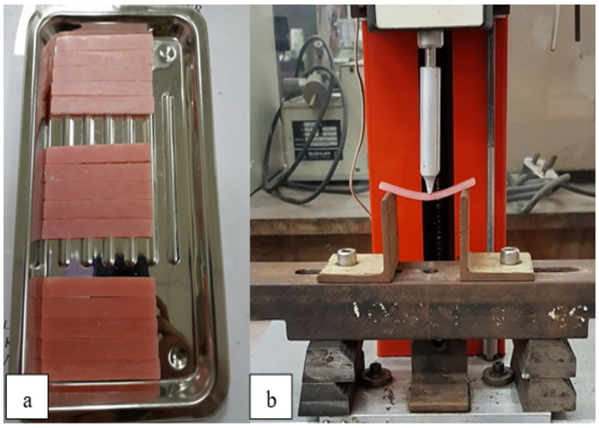

Figure 3. a Acrylic resin samples; b Flexural strength test

was in accordance with the standard procedure of packing process and heat-cured QC-20 (Dentsply®) acrylic resin polymerisation with added TiO2 nanoparticles. The mixing of nanoparticles TiO2, polymer and hot acrylic resin monomer monomers were mixed in comparison according to Table 1. The division of TiO2 nanoparticle concentration based on previous studies by Alwan and Alameer9 as follows:

All test plates were immersed in aquadest for 48 hours at 37ºC before a flexural strength test was performed.11 Specimens were tested for flexural strength using a Universal Testing Machine. The flexural strength data is calculated using the Modulus of Rupture formula (at a three-point bending setup).[12]

The data analysis used to determine the effect of TiO_2 nanoparticle concentration on flexural strength of denture plasterboard acrylic resin was the one-way ANOVA and if there was a significant difference followed by the Least Significant Difference test with 95% confidence level ($p < 0.05$) as shown in Figure 3.

RESULTS

Research on the effect of concentration of nanoparticles TiO_2 on the flexural strength of denture acrylic resin polish plate was performed in the Laboratory of Materials Science Department of Mechanical Engineering Faculty of Engineering, Gadjah Mada University Yogyakarta, Indonesia. The result of flexural strength can be seen in Table 2.

The highest flexural strength was found in the 1% nano TiO_2 concentration group of 106.99 MPa, and the lowest flexural strength was found in the 3% TiO_2 particle concentration group of 91.64 MPa. The results of this study were tested using the one-way ANOVA with normality test requirement using Shapiro-Wilk ($p > 0.05$), and homogeneity test using the Levene test ($p > 0.05$) must be fulfilled.

Data were tested by using one-way ANOVA with variable concentration result there was significant difference with p = 0,000 ($p < 0.05$). ANOVA test data can be seen in Table 3.

Table 1. Comparison of TiO_2, polymer, and monomer

Concentration group	TiO2 weight (gram)	Polymer weight (gram)	Monomer (ml)
A (0% TiO_2)	0	50	22.7
B (1% TiO_2)	0.5	49.5	22.7
C (3% TiO_2)	1.5	48.5	22.7

Table 2. Mean and deviation standard of flexural strength (MPa) in all concentration groups

Concentration group	Mean (MPa) (X ± SD)
Control	96.22 ± 4.96
1% TiO2	106.99 ± 6.09
3% TiO2	91.64 ± 5.38

Table 3. Results of Post Hoc LSD test between all concentration groups of nanoparticel TiO_2

Group	Compared group	LSD test value	Significant value
Control group	1% of TiO2 group	-10.77	0.000*
	3% of TiO2 group	4.58	0.090
1% of TiO2 group	Control group	10.77	0.000*
	3% of TiO2 group	15.35	0.000*
3% of TiO2 group	Control group	-4.58	0.090
	1% of TiO2 group	-15.35	0.000*

Notes :(*) showed significant difference ($p < 0.05$)

The concentration variables have a significant difference ($p < 0.05$) so that continued with the Least Significant Difference (LSD) test.

DISCUSSION

The average result of the highest flexural strength measurement in the nanoparticles group of TiO_2 concentration of 1% was 106.99 MPa. This condition was because the nanoparticle TiO_2 acts as a filler on the PMMA matrix chain which resulted in the pressure given when the flexural strength test was distributed to the nanoparticles of TiO_2 spread evenly among the PMMA matrix with the help of silane. This result was in accordance with previous research which stated that the presence of nanotube TiO_2 was able to prevent the occurrence of crack propagation on acrylic resin denture plate.[13]

The 3% nanoparticles TiO_2 concentration group had the lowest average of 91.64 MPa. This result was because the excessive concentration of the TiO_2 nanoparticles caused the polymerisation of the imperfect acrylic resin so that the porosity increases and the acrylic resin had become more brittle so that it easily broke during the flexural strength test. This condition was in accordance with the opinion of Ahmed et al. which states that the concentration of excessive TiO_2 nanoparticles may increase the porosity of the acrylic resin plate.[14]

One-way ANOVA test results in Table 3 showed a significant difference in the concentration group of 1% and 3% of TiO_2 nanoparticles to the flexural strength of denture acrylic resin (0.05). This was because the TiO_2 nanoparticles acting as fillers can fill the empty spaces between PMMA chains without changing the basic structure of the PMMA chain. Proper filler concentration was able to increase PMMA matrix density, whereas excessive filler concentration may interfere with acrylic resin polymerisation process and dnanoecrease the mechanical strength of acrylic resin, including flexural strength.

This result was consistent with the opinion of Alwan and Alameer which stated that the addition of nanotubes TiO_2 filled the void space between PMMA matrices and did not change the basic structure of the PMMA chain.[9] The study of Nazirkar et al. proofed that the excessive concentration of TiO_2 nanoparticles may interfere with the polymerisation process of acrylic resins.[15]

The LSD test results showed that the flexural strength of the nanoparticles group TiO_2 concentration of 1% compared with the control group significantly increased ($p < 0.05$). Increased flexural strength due to silane will increase the surface energy of TiO_2 to form strong bonding bonds with the interfacial attachment between the TiO_2 nanoparticles and the polymer matrix of PMMA resulting in increased van der Waals forces and increased crosslinking of the chain polymer. The increased inter-molecular attraction forces result in shear strength between the TiO_2 particles and the PMMA matrix getting larger so that the flexural strength increases. The nanoparticles TiO_2 also decreases the porosity of the acrylic resin and modifies the surface of the acrylic resin to hydrophobic thus reducing the water sorption. This result was consistent with Salman and Khalaf's suggestion that silane was able to guarantee a homogenous distribution of nanoparticles within the PMMA matrix and form strong bonds between nanoparticles and PMMA matrices.[16] Acosta-Torres et al. proofed in their research that the porosity level of acrylic resin in the group receiving TiO_2 nanoparticle addition was lower when compared to the control group.[17] Harini et al. stated that the TiO_2 nanoparticles has changed the properties of the acrylic resin to hydrophobic thus reducing the water sorption.[12]

The results showed that the flexural strength of the 3% TiO_2 particle concentration groups compared with the 1% nanoparticles group of TiO_2 concentrations decreased significantly, this was because an increase in excessive TiO_2 nanoparticles may increase the risk of uneven mixing between polymers resulting in more monomers does not react to polymer so that the residual monomer increases and reduces crosslinking between the polymer chains. The residual monomer acts as a plasticiser since it was able to enter between the polymer chains which cause the separate chains to become more tenuous and the attraction force between molecules decreases so that the acrylic resin becomes more flexible but brittle during the flexural strength test. In the opinion of Shirkavand and Moslehifard, the addition of excessive TiO_2 nanoparticles may cause the agglomeration of the TiO_2 nanoparticles, so the microporosity and the microcrack of the acrylic resins were increased and caused a decrease in the flexural strength of the acrylic resin.[8] Research conducted by Nazirkar et al. proofed that the addition of excessive TiO_2 nanoparticles may interfere with the polymerisation reaction of the acrylic resin resulting in an increasing unreacted monomers being polymers.[15] The results showed that there was no significant difference ($p > 0.05$) between the nanoparticles group TiO_2 concentration of 3% and the control group, the flexural strength of the TiO_2 nanoparticles group with 3% concentration decreased but not significant.

The decreased flexural strength due to the excessive addition of excessive TiO_2 nanoparticle filler may, therefore, be at risk of clumping during the mixing process between the TiO_2 and PMMA nanoparticles thus disrupting the polymerisation process of the acrylic resin.[7]

CONCLUSION

From this study can be concluded that concentration of 1% of nanoparticles TiO_2 was able to increase the flexural strength of acrylic resin denture plate. Further research was needed regarding the effect of nanoparticles TiO_2 concentration towards the residual monomer amount on an acrylic resin plate denture

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