The difference of surface roughness in acrylic resin self-cured with addition of zirconium dioxide particles as a denture repaired materials

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ABSTRACT
Background: Tooth loss is one of the effects of periodontal disease and dental caries. Tooth loss can be resolved by making a denture prosthesis. Several factors that influence society on denture use include aesthetic, social, functional, educational, and cultural factors. The large number of lost teeth will certainly increase the demand or desire to manufacture dentures to restore the function of the missing teeth. One of the materials that are often used in dentures is acrylic resin. Acrylic resins frequently used for denture base materials are cold polymerized acrylic resin and hot polymerized acrylic resin. Cold polymerized acrylic resin uses chemical activation, and this type of resin is often used for denture repair materials. Denture repair aims to repair prostheses that have many fractures in the midline area. Chemical polymerization acrylic resin is often used as a repair material because it is easy to apply and can be done directly on the patient. This resin has a disadvantage because it often leaves residual monomer in the polymerization process, so it impacts porosity. This problem can be overcome by modifying the resin's chemical structure using polyethylene glycol or by adding ZrO_2. **Objective**: This study aims to determine the effect of adding 3%, 5%, and 10% of zirconium dioxide (ZrO_2) nanoparticles to the surface roughness of self-cured acrylic resin as a denture repair material. **Methods**: Four sample groups, each consisting of 10 samples, were divided into the control group (K), the treatment group with ZrO_2 addition 3% (P1), the treatment group with the addition of ZrO2 5% (P2), and the treatment group with the addition of ZrO_2 10% (P3). The results of all treatments and controls were tested for surface roughness using the MST-301 surface roughness test profilometer. **Results**: Based on the results of the descriptive test, the mean of group K = 0.395 ± 0.161, group P1 = 0.813 ± 0.525, group P2 = 1.284 ± 0.336 and group P3 = 1.093 ± 0.558. In the Kruskal-Wallis test, there were significant differences in all groups. **Conclusion**: The self-cured acrylic resin with the addition of 3% concentration of ZrO_2 has the lowest surface roughness compared to the other groups, and the roughness is almost similar to the surface roughness of the control group.
Keyword: resin akrilik self cured, zirconia dioksida, kekasaran permukan

INTRODUCTION

Based on the results of primary health research (RISKESDAS) in 2013, the prevalence rate of dental and oral diseases was 25.9%. The national tooth loss percentage at the age of 35-44 years is 0.4%, and it increased at the age of 65 years and over to 17.6%.[1] Several factors that influence society on denture use include aesthetic, social, functional, educational, and cultural factors. The large number of teeth lost will undoubtedly increase dentures' demand to restore the missing teeth' function.[2]

One component of the dentures is the denture base, which can be made of metal or alloys, and polymers.[3] The denture's basic function here is to replace the lost alveolar bone, improve facial aesthetics, and deliver occlusal pressure to the tooth-supporting tissue and the residual alveolar ridge.[2] Acrylic resin is one of the selected materials in the manufacture of removable denture bases to date. This material is often used in dentistry because it has various advantages such as biocompatibility, satisfactory elastic quality, low water absorption, good thermal conductivity, and easy processing and repairing.[4]

This study used acrylic resin; specifically, it was a chemical polymerized resin.[3] This material is commonly used for restoration materials, removable orthodontic tools, denture repair, and the manufacture of special printing spoons.[5]

Polymethyl methacrylate (PMMA) resin has low mechanical properties, so it often experiences denture base fractures.[6] Fractures in the denture base can occur either outside the mouth due to hard impact, accidentally falling during cleaning, or inside the mouth caused by small but repetitive occlusal loads. A very small, one-time load does not appear to have any visible impact on components. However, this creates tiny cracks that can only be seen microscopically. With similar events continuing, these tiny cracks will coalesce into gaps that weaken the material.[7] Other statistical data shows that fractures frequently occur in the midline of removable dentures, which is 35% of the total 320 samples where fractures in the midline of the maxillary dentures are more common than those of the mandible.[8]

Chemical polymerized acrylic resins have lower transverse strength than hot polymerized acrylic resins.[9] Chemical polymerized acrylic resins also have large porosity due to the air in the monomers that are insoluble in the polymer at room temperature. The rheological properties of chemical polymerization acrylic resin materials are also lower than hot polymerized acrylic resin. Therefore, chemical polymerization acrylic resin tends to be used in small-scale prosthodontics applications, such as in denture repair, ortho devices, and many more.[3]

The problem of mechanical properties of acrylic resin can be minimized by increasing the strength of the resin. Several ways have been done to increase acrylic resin's strength, for example, by adding 3%, 5%, and 10% ZrO_2 nanoparticles.[10] To obtain good biocompatibility of the materials, the surface roughness of the material must be minimized.[11] Surface roughness is critical in determining restoration success because a rough and porous surface can result in developing microorganisms' preference conditions.[12] One of the requirements for fine acrylic resin materials for use in the oral cavity is a well-polished surface of the resulting resin material to reduce organic debris retention. Therefore, surface roughness is one of the considered characteristics.[13] Clinically, the threshold value for denture base surface roughness is 0.2 μm.[14] The best addition of ZrO_2 nanoparticles with concentrations 2%, 3%, 5%, and 7% on the acrylic resin in increasing the impact of strength and transversal is a concentration of 5%.[15] Zirconium dioxide has a high strength and hardness, is resistant to abrasion, non-toxic, biocompatible, low thermal conductivity, better thermal strength than aluminia, and has corrosion resistance.[16] The addition of zirconium dioxide (ZrO_2) nanoparticles as a coating on PMMA has been suggested to improve PMMA properties.[17]

Silane is a linking material used to make bonds between organic and inorganic materials simultaneously. Silane is used to modify the surface of inorganic materials to increase the adhesion between organic and inorganic materials.[18]

This study aims to determine the effect of adding ZrO_2 nanoparticles to the surface roughness of self-cured acrylic as a denture repair material.

METHODS

This research was a true experimental research with a post-test only control group design. The sample used was blocks with a size of 15x15 x1.5 mm as many as 40 pieces, made of self-cured acrylic resin added with ZrO_2, which was divided into four groups, where the chosen criteria were smooth and flat, non-porous surfaces, shape, and size according to the criteria.[19]

This research was started from the manufacture of the main model with a size 50x20x3 mm which was planted in the cuvette. Cold mold seal applied to the hard cast surface on the lower and upper cuvettes and left for a few minutes. Stir the polymer and self-cured acrylic monomer with a ratio of 3 g:4.5 g in a porcelain pot to the dough stage, then put it in the bottom cuvette mold. Cellophane plastic is placed between the top and bottom cuvettes, close the cuvette, and pressed with a hydraulic press with a pressure of 1000 psi. Open the cuvette and excess cut acrylic with a *lecron* mass, then close the cuvette again. Press the second with a pressure of 2200 psi, then install the bolts. Remove the sample, and the excess acrylic is also removed with a *fraser* bur and smoothed with waterproof sandpaper and number the sample using a marker. In the polymerization procedure, mix the self-cured acrylic resin material without the addition of ZrO_2 with the polymer and monomer ratio according to the factory dosage, then wait for the set time. The next group was given the silanization of ZrO_2 nanoparticles, which increased adhesion between the ZrO_2 nanoparticles and the resin matrix. To increase the adhesion of the material, a ZrO_2 silanization process is needed to place 30 g of ZrO_2 nanoparticles into an erlenmeyer tube containing 200 mL of pure ethanol, which was used as a solvent. Then the erlenmeyer tube was put into the sonicator at room temperature for 20 minutes. Then, vibrate it for 20 minutes at room temperature using a magnetic stirrer so that the ZrO_2 nanoparticles and ethanol were mixed homogeneously. After that, the solution was added to the silane coupling agent as much as 1.5 mL (3%, 5%, 10% of the ZrO_2 nanoparticles) into the ZrO_2 nanoparticle mixture and ethanol using a sterile syringe and then vibrated with vibration of 250 rpm for 60 minutes.

Pour the mixture in a closed container and left for two days at room temperature so that the substance dissolved by the silane coupling agent can completely absorb at the ZrO_2 surface. The ethanol mixed in the ZrO_2 nanoparticles was evaporated using a rotary evaporator with a temperature of 60°C and a speed of 150 rpm for 30 minutes to separate the ethanol solvent and the silane coupling agent mixture that had been fused with ZrO_2.

Remove the remaining ethanol and silane coupling agent using a vacuum buffer tool. Then, the silanized ZrO_2 nanoparticles were dried in an oven at 60°C for 20 hours, then removed from the oven. Next, ZrO_2 nanoparticles were processed using a sonicator at a speed of 250 rpm for three minutes to break down clumped particles, then sonicate again for three minutes to mix the monomer and ZrO_2 to become nanoparticles again.

Mixing of self-cured acrylic resin was done by the addition of ZrO_2 nanoparticles with a concentration of 3%, 5%, 10%. The ZrO_2 nanoparticles that had been silanated were weighed as much as 0.54 g for one cuvette consisting of 3 impact strength samples. The calculation was equivalent to 3%, 5%, 7% of the polymer, and monomer's total weight. The ratio of ZrO_2:polymer:monomer for filling mold compressive strength was 0.54 g: 11.46 g: 6 mL. Stir the nanoparticles, polymer, and monomer in the capsule until they were homogeneous.

Surface roughness measurements used a profilometer, which was calibrated in advance. The sample was placed in the space provided (table 1) so that the measuring device can move freely to the surface of the sample being measured for surface roughness. To control whether the tool had touched properly or been too pressing can be seen on the monitor screen. When the start button was pressed, the tool will move at a 1 mm/second speed. After that, the results were recorded.

RESULT

The data obtained were tabulated, and statistical analysis was carried out to obtain a description of the distribution and summarization of the data to clarify the results' presentation. Hypothesis testing was carried out using analytical statistics with a significance level of 95% (p=0.05) and processed with the program SPSS version 24.

Table 1 The results of the mean calculation of the surface roughness test (surface roughness)

Group	Mean±Std.Deviasi
K	0.3950 ± 0.1609
P1	0.8130 ± 0.5254
P2	1.2840 ± 0.3364
P3	1.0930 ± 0.5588

Table 1 shows that the highest mean value of surface roughness was found in group P2 (1.284 ±0.3364), while the lowest surface roughness was found in group K (0.395 ± 0.1609). The results of this study indicate that the concentration of self-curved acrylic with the addition of ZrO_2 results in the P2> K> P1 group, which means that P2 is more effective than K and P1.

The normality test results using the Shapiro-Wilk test showed that the P1 and P2 groups were normally distributed, while the P3 groups were not normally distributed. The data results were known not to be normally distributed; therefore, the test was continued using Kruskal-Wallis.

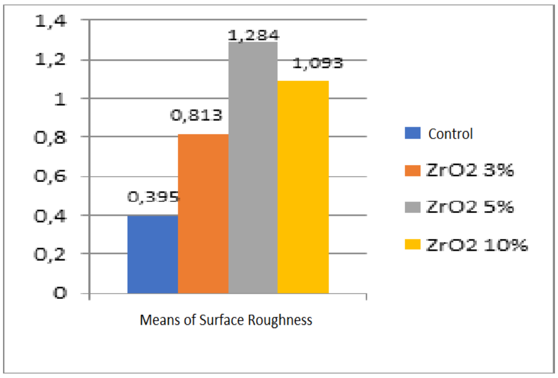

Figure 1 Diagram of means and std.deviation surface roughness in self-cured acrylic

The Kruskal-Wallis test results showed a significance value of p=0.000 (p<0.05), so there was a significant difference in each group. From the results of the Kruskal-Wallis test, the Mann-Whitney test was continued to see the difference in surface roughness between each group.

DISCUSSION

This research was conducted to determine the effect of 3%, 5%, and 10% of ZrO_2 nanoparticles on the self-cured acrylic denture repair material. Self-cured acrylic resin is an acrylic resin whose chemically activated-polymerization.[20] Zirconium dioxide is zirconium oxide stabilized in the tetragonal phase (t-ZrO_2), primarily as a core or framework for dentures.[3]

According to the research results, there was a change in surface roughness on the self-cured acrylic resin plate, which was added with zirconia dioxide filler. The greater the concentration of the addition of zirconia filler to self-cured acrylic, the more changes in surface roughness will occur. It was evidenced by the significant difference between group K and group 5% and 10%.

This difference is due to the addition of ZrO_2, which has a very small particle size that easily spreads into the self-cured acrylic resin. This characteristic of zirconia makes these zirconia particles enter between the linear polymer chains and increased surface roughness, but the higher the concentration of ZrO_2 added to the self-cured acrylic resin, the color of the acrylic resin plate turns whitish, thus disturbing the aesthetics. The reason for choosing zirconia as a self-cure acrylic resin filler is because zirconia material has good mechanical properties and high compressive strength.[21] Good mechanical strength is very supportive of denture plate repair materials. The addition of zirconia filler can stabilize the transformation of the crystal structure due to the heating process.[22]

In mixing zirconia as a filler in self-cured acrylic resin, less temperature is used as the initiator during its polymerization. The greater the concentration of zirconia added, so the greater the surface roughness obtained because the heating temperature required during the acrylic polymerization process has not reached the best maximum temperature to obtain the mechanical strength of the properties of the zirconia material. Therefore, the maximum concentration of ZrO_2, which can meet surface excitation requirements while having mechanical strength, is obtained at a 3%.

The results also stated that in the group, the addition of 5% zirconia compared to the addition of 10% zirconia, there appeared to be no significant difference; this was because at a concentration of 10% there was a slight error during the polymerization process and the sample polishing process. Errors in the polishing process affect to surface roughness of the sample.

It was concluded that self-cured acrylic resin with the addition of ZrO_2 3% has the smallest surface roughness and the mechanical strength of the self-cured acrylic resin material achieves the strength expected of the denture repair material.

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