ORIGINAL ARTICLE

Effect of PVA-PEG Binders on Surface Roughness of Y-TZP Zirconia

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ABSTRACT

Introduction: Y-TZP Zirconia is a ceramic used for dental implants because it has good biocompatibility and aesthetic properties, and it is affordable. Y-TZP formed from powder using uniaxial pressing with some added binder. The binders used are PVA, PEG and a combination of both. This combination reduce hardness and improve plasticity properties. Significantly increasing of the binder concentration and the surface roughness of the implant increases the porosity of the material as a place for the osseointegration process. Thus, the purpose of this study was to examine the different effect of PVA-PEG binders on the surface roughness of Y-TZP zirconia. **Methods:** Twelve samples were divided into three treatment groups: 100% PVA, 100% PEG and 4% PVA-PEG added to Y-TZP powder at a ratio of 95:5 (wt.%). The mixture was pressed using a uniaxial pressing machine, sintered and measured: the data was then analyzed using one-way ANOVA and Post Hoc LSD. **Results:** The result of the ANOVA showed that there were significant differences in the surface roughness of the Y-TZP with three different binders ($P<0.05$). The average surface roughness of the three binders are as follows: PVA 100% (0.8025±0.23472), PEG 100% (1.2325±0.23866), 4% of PVA-PEG (1.3450±0.27695). The LSD showed that there was significant differences between PVA 100% and PEG 100% ($P<0.05$), PVA 100% and 4% PVA-PEG ($P<0.05$). There was no significant difference between PEG 100% and 4% PVA-PEG ($P>0.05$). **Conclusion:** 4% PVA-PEG binders combination has effects on the surface roughness of Y-TZP zirconia

Keywords: Zirconia Y-TZP, PVA, PEG, Surface Roughness, Dental implant

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INTRODUCTION

A dental Implant is one of the treatments conducted to replace one or more missing teeth (1). Selecting the right material is one of the keys to the long-term success of dental implants (2). The implant material must have biocompatible properties so that osseointegration can be achieved.(3) Surface roughness in titanium implants became the standard in dentistry implants (4). Surface roughness was then was divided into three types (Sa): machined/minimum (± 0.5 µm), moderate (1.0-2.0 µm), and rough (> 2.0 µm) (5). According to clinical research the highest survival rate was found in implants with moderate surface roughness. Additionally, the loss from the increased amount of surface roughness can be a source of bacteria on the surface of the implant (6). According Ananieva (7), Kocuria spp can lead to plaque-associated disease in the oral cavity and peri-implant mucositis. When the implant is exposed, its rough surface can become an attachment site for plaque (8).

Titanium was commonly used in dental implants because of its biocompatibility, resistance to corrosion, high mechanical strength, and light weight (9). However titanium has its disadvantages: it can cause hypersensitivity types I and IV and allergic reactions with a percentage of 0.6% (10). Despite this, patients still prefer aesthetica dental implants (11). Based on the research conducted by Van Brekel et al (12), the mucosal portion that covers the dental implant abutment has a thickness of 1 mm at a height of 0.2 mm from the gingival margin and a thickness of 2 mm at a height of 1 mm from the gingival margin. Titanium dental implants can affect the color of the gingiva with a thickness of less than 2 mm, thereby reducing their aesthetics. Because of the disadvantages of using titanium, zirconia ceramic materials were developed as dental implants (13). There are some differences between titanium and zirconia Y-TZP implant material. Y-TZP has more stable mechanical strength, better biocompatibility and aesthetic, lower price and less hypersensitivity reactions than titanium (14). Y-TZP also has lower bacterial adhesion (15).

The binder was added to the process of pressing ceramic powder to activate the material'a plasticity properties and achieved ceramic formation(16). It acted as a granule holder so that it could maintain its shape and increase the density of the ceramics after going through the sintering process (17). The binders used in the formation of ceramics were polyvinyl alcohol (PVA) and polyethylene glycol (PEG) (18). PVA is commonly used in the ceramic industry. It maintains the compaction of ceramic after it hasa been compacted and pressed for sintering. PEG is also frequently used when making ceramics. PEG combined with PVA can reduce the glass transition temperature (Tg) of PVA, which would increase the ceramics the ceramics plasticity properties (19).

According to Apituley,(20) the surface roughness that almost met the biocompatible requirement of an implant material was 4% combination of PVA-PEG. Based on Mohanty (17) research the addition of binder concentrations at 2%, 3% and 4% will increase the porosity of the material after sintering because of the process of binder removing (binder burnout). The increasing of porosity due to binder loss of loss will increase the material's surface roughness (21,27). This study was to examine the different effect of PVA-PEG binders on the surface roughness of Y-TZP zirconia to materials porosity.

MATERIALS AND METHODS

This study used the "post-test only" control group design. The 12 samples of zirconia Y-TZP in this study were divided into three groups: the group with 100% of PVA binder concentration, the group with 100% of PEG binder concentration and the group with 4% of PVA-PEG binder concentration.

A total of 20 grams of PEG powder were stirred with a spoon in 100 ml of distilled water in a glass beaker until it had dissolved completely (22). Ten grams of PVA powder were mixed with a magnetic stirrer in 100 ml of distilled on a hot plate at a temperature of 80 C and at a speed of 500 rpm for two hours (23).

A total of 0.42 grams of Y-TZP powder were mixed with 1 wt.% PVA binder and 1 wt.% PEG. A total of 2.02 grams of Y-TZP powder were mixed with 1 wt.% PVA-PEG binder with a ratio of 95: 5 wt.% for the 4% treatment group (24). The mixture of Y-TZP powder and binder was then placed into a 15 mm x 15 mm x 1.5 mm steel mold that was previously a zinc stearate lubricant material. Punch, which was part of the mold was installed and pressed using a 20-ton hydraulic press (TEKIRO) with a pressure of 150 Mpa for 20 seconds (25). The bottom of the steel mold was removed and repressed with 20-ton hydraulic press to release the pressing results.

Pre-sintering and final sintering were done to increase mechanical strength and eliminate all existing binder particles. Pre-sintering began at 9500^{o}C for 1 hour , then cooled to 230^{o}C in the oven. Final sintering was completed at 12000^{o}C for 4 hours.

To conduct a surface roughness test, samples in a transverse position on surface roughness instrument. Measurements must be taken three times for each of the points previously marked; the three results obtained will be averaged (26). In this study the data result was homogeneity, and then it analyzed using one-way ANOVA and Post Hoc LSD.

RESULTS

The data showed that zirconia Y-TZP in the 4% PVA-PEG binder group had the highest surface strength (Fig.1, Table I). Homogeneity test results using Levene's Test showed a significance value of 0.925 which can be interpreted as P> 0.05, the data had a homogeneous variant.

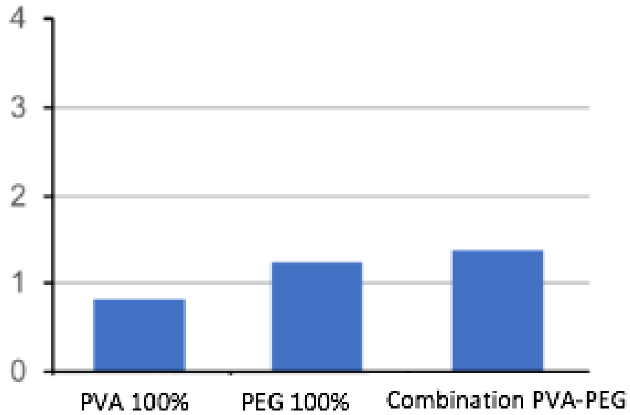

Figure 1: Diagram of average Y-TZP zirconia surface roughness with addition of PVA, PEG, and 4% of combination of PVA-PEG

Table I: Surface Roughness

	Means (µm)	Standard Deviation
PVA 100%	0.8025	0.23472
PEG 100%	1.2325	0.23866
PVA-PEG 4%	1.3450	0.27695

One-way ANOVA on the surface roughness of zirconia Y-TZP showed a significance value of 0.031 (P <0.05) which means there were significant differences between the three treatment groups. Because the significance value was less than 0.05 (P<0.05) (Table I), there werw significant differences in group with the addition of a PEG binder and combination of PVA-PEG binder. . It means surface roughness in Y-TZP materials with the addition PEG or combination PVA-PEG has higher value than PVA binder.

DISCUSSION

Table I shows that the highest surface strength zirconia Y-TZP is in the group with the addition of the 4% of

Table II: Post-Hoc LSD statistical analysis

Group	PVA	PEG	Combination of PVA-PEG
PVA		0.038*	0.014*
PEG			0.542
PVA-PEG			

*P<0.05 (there are significant differences)

PVA-PEG binder. This is because increasing the concentration of the binder can increase the porosity of a material after it goes through the sintering process (21). The sintering process can produce a coarser material because the high temperatures used during the sintering process can remove binders and result in empty spaces or gaps between particles (27).

The results of Post-Hoc LSD statistical analysis (Table II) showed a significant difference in surface roughness in the groups with the addition of PVA, PEG, and 4% combination of PVA-PEG. The group with the addition of 4% combination PVA-PEG had the same highest roughness with the PEG, a because hydrogen bonds hydrogen bonds between the two macromolecules had formed while mixing the two binders (25). PVA binder did not worked alone, it depend on with PEG as a binder in ceramic processed (19). PEG as an organic binder for zirconia ceramic is more valid in comparison with PVA when the samples strength was about 700 MPa (22). According the biocompatibility implant materials Y-TZP should have flexural strength 900-1200 Mpa (28). On the other hand the combination PVA-PEG binder chose the -OH group, which was capable of binding to the material in zirconia Y-TZP to form hydrogen bonds (29). The sintering process was carried out to remove binder particles, it was expected that the material had porosity as a result of losing some of the binder (30). In zirconia ceramics, the sintering process is conducted at 12000^{o}C. The binder itself will disappear due to the heating process occurring at a temperature of 600-7000^{o}C for pure polymers and even higher in ceramic powders. Binder decomposition started at 200-4000^{o}C where the C-H and C = O bonds disappear, while the C = C bond increases at 5000^{o}C and slow down at 8000^{o}C (31). The loss of binder bonds during the sintering process will cause pores on the surface of the sample and reduce its density. Every addition of 5% PEG has a higher porosity after the sintering process (32).

Porosity could be result from binder loss and it may increase unstable ceramic surface roughness (33). The surface roughness of 4% PVA-PEG (1.3450 μm) and PEG 100% (1.2325 μm) are suitable with the implant surface roughness value 1-2 μm (34) (Table I). Based on Apituley's research (2019), the surface roughness in Y-TZP material can increase if a 4% combination of PVA-PEG binder is added. This increase in surface roughness occurred with an increase in the concentration of the binder combination. The addition of the PVA or PEG binder had not been able to cause the desired surface roughness; this was proven by the concentration of the addition of a PVA-PEG binder seen using an electronic microscope (SEM), which showed increasing porosity at the highest PVA-PEG concentration. This pore size was counted in the biocompatibility of the implant material to ensure that the material was osseoinductive and could go through osseointegration (35).

In the research conducted by Ekka (36), ceramic alumina made with a PVA binder mixture had higher mechanical strength compared to those that used a PEG binder. PEG was used because of its nature as a plasticizer in PVA; PVA has the plasticity properties needed in the uniaxial pressing process to improve the mechanical properties of ceramics (37). The greater the ratio of PEG mixed with PVA, the more it can reduce the compressive strength of the Y-TZP material (24). PEG as a binder does not increase mechanical strength as well as PVA. Based on this research, the addition of PEG binder and the combination of PVA-PEG was had same effect in surface roughness for Y-TZP materials, but it is not quiet enough for the another characteristic Y-TZP for implant materials since the addition of PEG had higher thermal stability compared to PVA. Therefore, in the sintering process, polymer removal will occur more than the addition of PVA (38).

CONCLUSION

Based on the result of this study, the addition of a binder with a 4% combination of PVA-PEG can increase the surface roughness of the Zirconia Y-TZP as an alternative dental implant materials.

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