Impact Strength of Y-TZP Zirconia in Various PVA-PEG Binders Concentration

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Abstract

Zirconia ceramics are widely used as dental implant material. Yttria-stabilized tetragonal polycrystalline zirconia (Y-TZP) have stable mechanical strength, low thermal conductivity, excellent aesthetics and did not caused hypersensitivity. Binders provided the plasticity necessary for ceramic powder pressing so the ceramic had a higher density. Polyvinyl Alcohol (PVA) and Polyethylene glycol (PEG) are binders commonly used in ceramic industry. Dental implant material should have a sufficient impact forced.

Study impact strength of Y-TZP with various PVA-PEG binders concentration.

Samples were prepared by mixing Y-TZP powder with PVA (K), PVA-PEG 95:5wt% (P1), PVA-PEG 90:10wt% (P2), PVA-PEG 85:15wt% (P3). Mixture were then put into a bar-shaped steel mold with a size of 55x15x15mm for subsequent pressing. Samples were then sintered in the oven of 1200^{o}C. Impact test were done using Charphy method.

Impact strength of K1, P1, P2, P3 were 1,417 J/mm^2, 1,380 J/mm^2, 1,362 J/mm^2, 1,345J/mm^2. There were significant differences in K-P1, K-P2, K-P3 and P1-P3. No significant differences found in P1-P2 and P2-P3.

Highest impact strength values was found in control group (K), while lowest impact strength was found in treatment group (P1>P2>P3). Higher concentration of PEG concentration lead to lower mechanical strength of PVA.

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Introduction

A tooth loss can be replaced by dental implant. Nowadays, the dental implant technology becomes simple with a wide variety prosthetic yet with a economical price. Dental implant gives a lot of advantages in stability and comfort compare to dentures.[1] The material selections used for the right implant become the main key of dental implant success in a long time terms.[2] Dental implant with titanium material commonly used for replacing tooth loss, however it has a disadvantage where it can cause hypersensitivity type IV for several patients due to the ion metal releasing that will create a protein which act as allergen. To overcome the disadvantage of titanium, there is a development of ceramic as an alternative for dental implant material.[3,4]

Ceramic material that can be used for an alternative dental implant in dentistry is zirconia. Zirconia ceramic biologically comparable to titanium which is the most commonly used in implant material.[3] Zirconia, specifically yttria-stabilized tetragonal polycrystalline zirconia (Y-TZP), shown a mechanical properties which has been improved until it become a suitable material for dental implant manufacture. Dental implant with material Y-TZP has a stable mechanical strength, a good biocompatibility because of the thermal and electric conductivity are low, good esthetic, as well as it doesn't cause a hypersensitivity reaction like titanium.[4]

Binder plays a role as a granule bond so that it can maintain the shape and increase the

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ceramic density after sintering process.[5] PVA (*Polyvinyl Alcohol*) and PEG (*Polyethylene Glycol*) is an organic binder that commonly used for forming ceramic. PEG that combined with PVA function to lower glass transition temperature (Tg) PVA so that plasticity of the ceramic increase.[5] PVA has Tg more than 60^0C that cause PVA not soft enough for pressing and needed to be combine with PEG to create ceramic with a higher density.[6] Tg is a temperature where a polymer change from a hard form into a soft material.[5] With addition of PEG on PVA can increase the elongation at break that shows the plasticity enhancement from PVA that combined with PEG. This plasticity is necessary for ceramic material that has been pressing to have a higher density.[6]

One of the mechanical strength that needed to be pay attention at manufacturing a dental implant is impact force. Impact force test can be conduct into 2 methods which is Charphy and Izod method. Charphy method is one the popular method because it is easy and simple.[7] The higher the impact force indicated the higher modulus elasticity of a materials that makes material resist toward collision that can cause fracture.[8]

Materials and methods

Samples used was Y-TZP powder with same weight and divided into 4 groups. 20 grams Y-TZP added with binder PVA 100 wt% for group control (K); 20 grams Y-TZP added with binder PVA-PEG 95:5 (7.6:0.4 ml) wt% for first treatment group (P1); 20 grams Y-TZP added with binder PVA-PEG 90:10 (7.2:0.8 ml) wt% for second treatment group (P2); 20 grams Y-TZP added with binder PVA-PEG 85:15(6,8:1,2 ml) wt% for third treatment group (P3) (Figure 1).

Every 2% ratio binder consists of 50 gram PVA-PEG binder powder mix with 1.25 ml of aquadest. The mixture of Y-TZP powder and binder then put into a mold with a size of 10 mm x 10 mm x 55 mm (based on *American Standard Testing Materials* (ASTM)[9]) before given lubricant zinc stearate material to make it easy to insert punch when pressing process. Punch is a part of the mold that has been installed and then conducted pressing with *Uniaxial Pressing Machine* with a pressure of 150 Mpa for 20 seconds. Pre-sintering 950°C for an hour and then cooled until 23°C inside muffle furnace. Final sintering will be done in a temperature of 1200^0C for 4 hours.

Figure 1. Y-TZP samples divided into 4 research groups.

Figure 2. Impact Tester Machine.

Impact force of the Y-TZP samples measured with Charpy method using *Impact Tester Machine* (Figure 2). Test object placed horizontally and held on the left and right. Object will be hit at the back notch part, right at the middle. The notch part will be at the back punch (the weight direction of imposition will be the opposite of the pulling force), and then pendulum

is lifted with a height of h (initial height) then specimen placed at the base and simultaneously releasing the pendulum that has a knife edge, strikes and fractured notch. The notch will keep swinging with a maximum height (h') that supposed to be lower than the initial height (h), then the impact forced energy (E) can be obtained with a calculation of the difference in potential energy from the notch before and after the test.

Fomula : E=h'-h

E is impact force (J/mm^2), h' is maximum height of the notch (^{o}), h is initial height of the notch(^{0})

Results

Data result of impact forced was analyzed by descriptive statistic and shown as below.

Group	N	Mean ± SD
K	4	1,417±0,0150
P1	4	1,380±0,0163
P2	4	1,362±0,0125
P3	4	1,345±0,0129

Table 1. Mean and Standard Deviation of Y-TZP Impact Force (Joule/mm2) with variety PVA-PEG Binder Concentration.

Variable	Sig
Impact Force	0,000*

Table 2. One-Way ANOVA Test of Y-TZP Impact Force with Variety PVA-PEG Binder Concentration.

*p<0.05 (There is a significant difference)

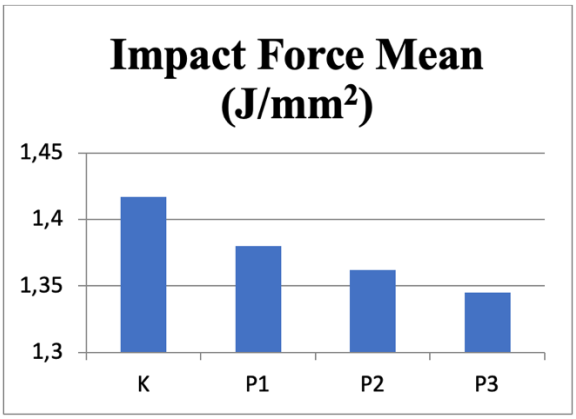

Figure 3. Mean and Standard Deviation Standard of Y-TZP Impact force (Joule/mm2).

The data varian were homogenic from *Levene test* (p>0.05) and distributed normally according to *Shapiro-Wilk* test (p>0.05). The highest mean ± standard deviation impact force of Y-TZP shown in control group (PVA Binder 100%) (1,417±0,0150) while group treatment P3 (PVA-PEG Binder 85:15 wt%) expressed the lowest mean ± standard deviation impact force (1.345±0.0129) (Table 1 & Figure 3).

ANOVA test was done to study the relationship between control group and treatment groups. There was a significant difference (p<0.05) within the control group and treatment groups (Table 2).

Then data were examied using LSD test to found the detailed information of group with significant difference. There were significant difference of impact force between group K-P1, K-P2, K-P3 and P1-P3. There is no significant differences between group P1-P2 and P2-P3 (Table 3).

Group	K (PVA 100%)	P1 (PVA-PEG 95:5%)	P2 (PVA-PEG 90:10%)	P3 (PVA-PEG 85:15%)
K		0,003*	0,000*	0,000*
P1			0.109	0,005*
P2				0,109
P3				

Table 3. LSD Test of Y-TZP Impact Force with Variety PVA-PEG Binder Concentration.

Discussion

Clinical longevity of restorations is the result of combination factors, such as materials mechanical properties, damaged caused by the processing methods and the cyclical loads to which materials are subjected when in use and its biocompatibility.[10] Impact force plays a crucial role in dental implant, because the higher the impact force of an object means the higher the modulus elasticity of that object so the object will resist toward collision that can cause fracture.[8] Materials with good impact force can be classified as a potential alternative of dental implant materials.[11]

This study aims to understand the impact force of Yttria-stabilized tetragonal zirconia polycrystal ceramics (Y-TZP) with variety of PVA and PEG binder concentration. Based on

ANOVA test, the value significance of impact force is 0.000 ($p<0.05$). This means that the difference in impact force between each groups is significant. This proven that impact force was correlated with the binder concentration of PVA and PEG.[5]

There was a significant difference between control group (2% PVA 100%) with P1 (2% PVA-PEG 95:5 wt%), control group (2% PVA 100%) with P2 (2% PVA-PEG 90:10), and control group (2% PVA 100%) with P3 (2% PVA-PEG 85:15) the reason is because at control group affected by PVA which increased the mechanical force of Y-TZP.[12] The more PVA concentration, will increased mechanical force of Y-TZP. The significant difference can be seen at P1 group with P3 group, because there is an effect from the amount of PEG binder that can decrease Tg from PVA binder. PVA has Tg higher than 60^{o}C so it is tough at room temperature, this allow PVA to increase the mechanical force of Y-TZP.[5]

There is no significant difference between P1-P2 and P2-P3 that signified there is no effects that can be define from P1-P2 and P2-P3 groups treatment. This happened because of the characteristic from PEG that has a low glass transition temperature (Tg), where the polymer with a low Tg (has more elastic chains) has a lower force so it makes the material become more fragile.[13] The impact force could also get lower due to the transformation effect of tetragonal phase to monoclinic phase of zirconia which happened due to the stressed force.[12] The decreasing impact force from P1, P2, and P3 might be affected by the manual stirring of polymer and monomer in this research, so was the difference in the stirring speed.[6] The difference in stirring speed result in the less homogen of Y-TZP sample used in this research. The stirring can be done using an instrument called Spray Dryer so that the result will be more homogeny. This stirring aim to mix Y-TZP with binder in order to gain a difference bond of impact force from an object[13], among others: the notch shape that take effect from the toughness of the material, the high carbon content that has a solid and brittle characteristic, high temperature on the specimen also cause an increase of toughness in receiving sudden weight.[11]

This study shown that Y-TZP with 2 wt% binder PVA (control group) resulting in highest impact force (1.417 J/mm^2). But the higher binder concentration did not contribute in higher mechanical force of the material. Study by Ghahremani *et.al* (2017) concluded that impact force of titanium was slightly higher than zirconia, but not too significant.[14]

Conclusions

Impact force of Y-TZP materials correlates with the concentration level of PVA:PEG. Control group was the group with the highest value in impact force, while in P1, P2, P3 groups shown gradually decreased impact force of Y-TZP. This due to PEG binder which decreased the mechanical force of PVA. Further study and analysis are needed with better setting to confirm this study.

Declaration of Interest

The authors report no conflict of interest.

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