Flexural strength comparison of self-synthesised porcelain with the sintering temperature of 1150°C and 1200°C

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ABSTRACT

Introduction: Porcelain must have sufficient flexural strength to withstand mastication forces. The flexural strength of porcelain can be influenced by the maturity level of porcelain related to the temperature and sintering time. The purpose of this study was to compare the flexural strength of Indonesian natural sand self-synthesised porcelain with different sintering temperatures. **Methods:** Self-synthesised porcelain powder, with the composition of 65% Pangaribuan felspar, 25% Belitung silica, 5% Sukabumi kaolin, and 5% potassium salt, were condensed into 10 samples with the size of 7cm x 2cm x 0.4cm. A total of 5 samples were each burned at the temperature of 1150°C and 1200°C. Flexural strength test was performed using the Universal Testing Machine (Netzsch™) with the lowest load of 7.5 kg, and the data obtained was calculated using the bending strength formula. **Result:** The average flexural strength of self-synthesised porcelain at the sintering temperature of 1150°C was 26.678 MPa, while at the temperature of 1200°C was 39.038 MPa. **Conclusion:** This study concluded that Indonesian natural sand self-synthesised porcelain had a lower flexural strength at the sintering temperature of 1150°C than at the temperature of 1200°C.

Keywords: Flexural strength, self-synthesised porcelain, sintering temperature

P-ISSN 1979-0201, e-ISSN 2549-6212 Available from:http://jurnal.unpad.ac.id/pjd/article/view/19307
DOI: http://dx.doi.org/10.24198/pjd.vol30no3.19307
Submission: May 23, 2017; Reviewed: Feb 27, 2018; Resubmit for review: Jul 17, 2018; Accepted: Oct 30, 2018; Published online: Nov 30, 2018

INTRODUCTION

Flexural strength is a mechanical property of porcelain which shows its ability as brittle material to resist masticatory forces. In its application as a restoration, porcelain must be able to withstand occlusal forces that are charged from opposing teeth or muscles.[1,2] Occlusal forces associated with the masticatory forces of the posterior region range from 700-760 N which means dental

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porcelain with a thickness of 1-2 mm must have a flexural strength of 100-120 MPa in the occlusal area of the posterior teeth.[1-3]

Flexural strength can be tested in various ways including three-point bending, four-point bending, or biaxial flexural strength test.[1,2] Felspathic porcelain has flexural strength between 60-80 MPa. This material has a lower strength than the material used for all-ceramic, this is because felspathic porcelain is usually supported by metals in metal-ceramic restorations. Zirconia has the highest flexural strength value of 800-1300 MPa, slip-cast porcelain has flexural strength between 378-630 MPa, while disilicate lithium porcelain is 262-306 MPa. The mechanical properties of the final product are strongly influenced by the number of crystalline phases present in each ingredient.[3-5]

The crystalline phase can improve some mechanical properties of porcelain, one of which is flexural strength. The bond between molecules of the porcelain base composition will produce one or more crystalline phases. The bond is formed on the base material that has undergone combustion (fritting & sintering). One of the crystals that can be formed is leucite (potassium aluminosilicate) as in the self-synthesis of porcelain from Indonesian natural materials.[6,7]

Crystallisation and the bonds between molecules formed are influenced by many factors. These factors include composition, mixing process, time and temperature of combustion. This study intends to compare the flexural strength of porcelain associated with the crystalline phase and the bond between molecules with different combustion temperatures.[8,9]

METHODS

This research was conducted in 3 stages, including sample making, combustion to obtain solid porcelain mass (sintering), and flexural strength test. Materials needed in this study included self-synthesis porcelain powder, mould from the phosphate-bonded cast, and aquadest; while the tools used included oven with a maximum combustion temperature of 1200°C, and Universal Testing Machine for testing flexural strength. The research was conducted in September-November 2016 at the Center for Ceramics, Bandung.

All samples were made from self-synthesis porcelain powder with a composition of 65% wt feldspar, 25% wt silica, 5% wt kaolin, and 5% wt of potassium salt. The basic ingredients have been mixed and melted before. Samples were made as many as 10 pieces to be sintered at 2 different temperatures each of 5 pieces. The sampling was performed by adding aquadest gradually to the porcelain powder on a phosphate-bonded cast mould with a size of 7cm x 2cm x 3mm.[7,10]

Sintering is porcelain powder combustion before reaching its melting point to obtain a solid mass of porcelain. The sintering process refers to the patent of translucent dentistry porcelain by Katz[11] and previous research; five moulds were put into an oven with an initial temperature of 30°C and raised 50°C/h until it reached a temperature of 1150°C and held for 1 hour. The temperature returned is reduced by decreasing the temperature of 250°C/hour until it reaches the initial temperature and the sample then taken out of the oven. The next five prints are put into the oven with the initial temperature and the same temperature increase until it reached 1200°C and held for 1 hour. The decrease in temperature until it reaches the initial temperature was also done the same as the previous combustion.[8,11,12]

Figure 1. Porcelain samples

Figure 2. Netzsch Universal Testing Machine

Table 1. Flexural strength test of self-synthesised porcelain with sintering temperature of 1150°C and 1200°C

Speciment number	FS 1150°C (MPa)	FS 1200°C (MPa)
1	28.271	55.387
2	29.802	31.421
3	22.961	28.958
4	26.394	33.222
5	26.410	46.201
Mean	**26.678**	**39.038**

The flexural strength test was carried out using a three-point bending technique. The tool used is the Universal Testing Machine Netzsch brand which has a range between 50 mm buffer, with a test lever diameter of 1.6 mm with the lowest load of 7.5 kg and the speed of addition of loads 0.25 kg/sec. Tests carried out at the Center for Ceramics, Bandung.[7,10] According to Fischer in 2008[10], the calculation of flexural strength is done by the flexural strength measurement formula from the data obtained on the Universal Testing Machine Test.

RESULT

In appearance, porcelain with a sintering temperature of 1150°C and 1200°C did not show a significant difference, but it was seen that bubbling occurred at combustion at a temperature of 1200°C. The results of the fault samples after flexural strength testing also showed that samples with sintering temperatures of 1200°C had quite a lot of pores. The results of the self-synthesis porcelain flexural strength test can be seen from Table 1.

DISCUSSION

Good self-synthesis porcelain with sintering temperatures of 1150°C and 1200°C still has flexural strength under the flexural strength of dental porcelain on the market (Ceramco II, Excelco, Vitadur-N, Vita VMK 68 ranging from 55 to 70 MPa). This condition can be caused by various things, such as the difference in the standard of testing performed. Although the test and calculation of flexural strength in this study have referred to ANSI/No. 69, this research cannot be entirely carried out according to the reference due to the limitations of the tool. Samples that should be made with a size of 2 cm x 5 mm x 1 mm with an initial load of 5.4 kg and the speed of adding a load of 0.1 kg/sec cannot be compared with the existing test equipment. With the initial load and the speed of adding a more significant load will cause the fractured sample to be faster and the measurement results to be able because the force borne by the specimen becomes a dynamic force.[1,2,8,9]

Differences of the flexural strength at 2 different combustion temperatures can be caused by the level of maturity associated with crystalline formation and porosity on porcelain. Crystalline formed on this self-synthesis porcelain was crystalline leucite. Crystalline leucite can be created from a bond between potassium, aluminium, and silicate molecules contained from the porcelain base. Crystalline leucite will increase the flexural strength of porcelain.[5,6,9]

The crystalline quantity of leucite on porcelain can be influenced by the elemental composition or maturity of porcelain. Sintering of porcelain with the right temperature and time will produce optimal crystalline leucite. However, to see the quantity of crystalline leucite at different combustion temperatures requires further research in the form of X-Ray Fluorescence testing.[10,13]

This research shows that with a sintering temperature of 1200°C can produce better flexural strength than the sintering temperature of 1150°C. The sintering temperature of 1200°C with a combustion time of 1 hour may be said to be the optimal temperature to obtain maximum flexural strength from the self-synthesis porcelain composition.[7,9,11] On the other hand, the sintering temperature of 1200°C can cause porcelain appearance bubbling and porous inside. These results showed that porcelain with combustion at 1200°C overheated. Overheating is caused by too high a combustion temperature so that some intermolecular bonds are broken and porous spaces are formed on porcelain. The overheating of porcelain will undoubtedly cause the appearance of porcelain to be less aesthetic, with many pores may reduce other mechanical properties.[8,13]

Pores formed on porcelain with a combustion temperature of 1200°C should produce low flexural strength. However, in this study, porcelain

with a combustion temperature of 1200°C has a higher flexural strength. This result may be caused by shrinkage in porcelain with a combustion temperature of 1200°C which is greater so that the porcelain dimension is reduced and influences the calculation of flexural strength using the formula. The flexural strength was inversely proportional to the dimensions of width and thickness so that the smaller the dimensions, the flexural strength becomes increasingly high.[8,9,11,13]

In previous studies, porcelain with such compositions showed sufficient sintering temperature to be carried out at a temperature of 1150°C. In this study, variations in the sintering temperature were carried out to see the potential of the porcelain composition at higher temperatures. In determining the appropriate temperature and combustion time, further testing is needed to obtain porcelain with sufficient maturity and produce good flexural strength.[7,8,13]

With the results of the flexural strength that is still below the standard, this self-synthesis porcelain can still be used as part of the body/dentin in the teeth with a not too large mastication force. In order to obtain porcelain with better mechanical properties, the time and temperature of sintering of self-synthesis porcelain must be readjusted.[2-4]

CONCLUSION

This study concluded that Indonesian natural sand self-synthesised porcelain had a lower flexural strength at the sintering temperature of 1150°C than at the temperature of 1200°C.

REFERENCES

1. Al-Makramani BM, Razak AA, Abu-Hassan MI. Biaxial flexural strength of Turkom-Cera core compared to two other all-ceramic systems. J Appl Oral Sci. 2010;18(6):607-12. DOI: 10.1590/S1678-77572010000600012.
2. Gozneli R, Kazazoglu E, Ozkan Y. Flexural properties of leucite and lithium disilicate ceramic materials after repeated firings. J Dent Sci. 2013;9(2):144-50. DOI: 10.1016/j.jds.2013.02.019.
3. Julien KC, Buschang PH, Throckmorton GS, Dechow PC. Normal masticatory performance in young adults and children. Arch Oral Biol. 1996;41(1):69-75. DOI: 10.1016/0003-9969(95)00098-4.
4. Junpoom P, Kukiattrakoon B, Hengtrakool C. Flexural strength of fluorapatite-leucite and fluorapatite porcelains exposed to erosive agents in cyclic immersion. J Appl Oral Sci. 2011;19(2):1-10. DOI: 10.1590/S1678-77572011000200003.
5. Sakaguchi RL, Powers JM. Craig's Restorative Dental Materials. 13th ed. St. Louis: Mosby-Elsevier; 2013. p. 253-76.
6. Helvey GA. Classification of dental ceramics. Inside Continuing Education. 2013; 13: 62-8.
7. Gunawan J. Sintesis dan uji kekuatan lentur porselen berbahan baku pasir alam campuran dari Pulau Sumatera dan Jawa [minor thesis]. Bandung: Universitas Padjadjaran; 2017. p. 40-60.
8. Boch P, Niepce JC. Ceramic materials. Processes, properties, and applications. 2nd ed. London: Hermes Science Publishing Ltd.; 2007. p. 130-55.
9. Carter CB, Norton MG. Ceramic materials. Science and engineering. 1st ed. New York: Springer-Verlag; 2007. p. 365-80.
10. Fischer J, Stawarczyk B, Hämmerle CH. Flexural strength of veneering ceramics for zirconia. J Dent. 2008;36(5):316–21. DOI: 10.1016/j.jdent.2008.01.017.
11. Katz S. 1988. Translucent dental porcelain composition, its preparation and a restoration made thereof. EP0272745A2.
12. Kitouni S, Harabi A. Sintering and mechanical properties of porcelains prepared from algerian raw materials. Cerâmica. 2011;57(344):453-60. DOI: 10.1590/S0366-69132011000400013.
13. Rahaman MN. Ceramic processing. 1st ed. Boca Raton: CRC Press; 2007. p. 365-81.