REINFORCEMENT OF PORCELAIN PRODUCTS BY ADDITION OF ZIRCONIA: A REVIEW

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ABSTRACT

This study describes an influence of zirconia addition on some porcelain properties, particularly mechanical properties such as hardness and strength, depending on results of some previous researches which describe the methods of porcelain strengthening and toughening due to use the porcelain in many applications in daily life, such as dental porcelain, electrical porcelain and sanitary ware from porcelain. Porcelain has very important properties which make it a suitable material to other promised applications. For this reason, it must be defined the last information to which the recent researches reached to benefit from those methods in an improving of the porcelain properties to use it in suitable applications. This study showed that it can be significantly benefited from the zirconia addition to porcelain in an improving of many properties for it.

Keywords: Zirconia, porcelain, strengthening, mechanical properties

INTRODUCTION

To improve the ceramics brittleness, different strengthening methods and developed processes technology have been proposed such as nano composite toughening, whisker toughening, coating toughening, or phase change toughening (Wang S.H., 2014, Leśniak M., 2016, Feng Q.H., 2019, and Xu X., 2023).

Porcelain is from the significant types of the traditional ceramics which employed much more area of diverse applications. It was produced by blend for the different white clays and fluxes which produced a dens body (Ismail, and Baspinar, 2005, and Saadon A.K., 2016). Porcelain has high thermal shock resistance which makes it a suitable material in many industries (Saadon A.K., 2016, William and Radford, 1987, and William R., 2013). Dental ceramic material is the preferential material to oral restoration because of several characteristics, for example chemical stability, high fracture strength and adequate esthetics. Porcelain is commonly utilized for fixed bridge work and the restoration of individual teeth due to its durability and natural appearance (Hamouda and

Beyari, 2013). Dental porcelain has a great glass amount, that provide the translucency required to esthetic restorations (O'Brien W.J., 2000). The brittle ceramics behavior and its low tensile strength by comparison with that expected for bond among atoms can be concluded with consider the stresses concentrations around the surface cracks. There is no yielding mechanism to stress without fracture in ceramics, as metals do, and therefore, the crack may propagate during a ceramic material at application low stress level. Therefore, the ceramic material has a tensile strength much lower than its compressive strength (Anusavice K.J., 1996, Wang R.F., 2011, Jia X.W., 2014, and Pei C.R., 2016). Methods utilized to outdo the lacks of ceramic material divide into two common categories, the first is strengthening methods of brittle materials and the second is components designing methods to minimize stresses concentration and tensile stress. One of strengthening methods of ceramic materials is reinforcement them by dispersed phases of different materials which are capable of deterring a crack to propagate during the material (Denry and Holloway, 2010, Atala and Gul, 2015, and Santos R. L. P., 2016). There is a newer method to strengthening ceramics includes the combination of crystalline materials that are capable for undergoing a transformation in the crystal structures when placed under stresses. Partially stabilized zirconia (PSZ) is the crystalline material commonly utilized for that purpose. The energy needed to transform of partially stabilized zirconia is taken of the energy which allow for the crack with propagation (Hamouda and Beyari, 2013, Anusavice K.J., 1996, and Denry I.L., 1996). Ceramics which contain on zirconia are good examples for the mechanism of transformation toughening. Zirconia is a polymorph material which takes three various forms of the crystal structures, which are: at room temperature is monoclinic, at 1170°C is tetragonal, and at 2370°C is cubic. A 5% volume reduction happens when the monoclinic phase transforms to tetragonal phase and 3% volume expansion happens during the transition of the tetragonal phase for the monoclinic phase. For stop these transformations, stabilizing oxides (like magnesium oxide and yttrium oxide) can be added for the material. These oxides permit for the tetragonal-phase particle to exist at room temperature, efficiently prevent the crack propagation and provide the high toughness (Gonzaga C.C., 2011, and Purushothaman S., 2023). Ceramic material used for the dental work and formed from Yttria stabilized tetragonal zirconia and feldspathic porcelain veneer has similar aesthetic and mechanical properties for natural teeth (Gómez J., 2019, Rueda A. O., 2013, and Balkenhol M., 2017). The zirconium element doesn't find in pure state on nature, but can be freely occurred as zirconium oxide ($ZrO2$) and with many combinations with silica oxide (Saadon A.K., 2016, and Piconi C., 1999). Several fundamental mechanisms of strengthening can be used for dental ceramics, from them crystalline reinforcement, thermal tempering and chemical strengthening (Hamouda and Beyari, 2013, and Denry I.L., 1996). Chyad F. A., (2015) investigated the effect of sintering temperature and magnesia addition on manufactured electrical porcelain properties, results of this study showed that when the sintering temperature and magnesia addition increase in the sample lead to increase of its dielectric constant, microhardness and density. Qzturk and Ay, (2012) investigated the influence of alkaline oxide on the density, porosity, firing shrinking, strength and composition of porcelain. Al – Bermany and Hashim, (2012) investigated the effect of ZnO, ZrO2 and TiO2 on the porcelain's properties, results of this study showed that ZnO, ZrO2 and TiO2 addition formed composite which give a good medium to transit the ultrasound waves, and it can be utilized as a coating materials for improving the coefficient of absorption for porcelain. Saadon A. K., (2016) studied the zirconia influence on some physical properties of porcelain, results of this study indicated that these properties alter significantly in the substituent specimen, and also that the increasing of zirconia content in the samples generates increase in bulk density and dielectric constant and decrease in dielectric loss tangent and open porosity as shown in figures (1, 2, 3 and 4).

Beyari and Hamouda, (2013) investigated the influence of yattria partially stabilized zirconia addition for dental porcelain, results of this study showed that 3% and 5% wt. of zirconia used as addition for the dental porcelain increase fracture toughness and flexural strength and decrease both the hardness and elasticity modulus for the porcelain specimens, while 7% wt. of zirconia used as addition decreases the properties above. Other study was used 0.5 and 2.5% wt. of zirconia -alumina as addition to improve the mechanical properties of commercial dental porcelain. Fracture toughness, hardness, color alterations and contact resistance were assessed to find the better performance for mechanical behavior in the new composites (Gómez J., 2019). Pereira R. L., (2015) studied use of porcelain-zirconia composite as dental ceramics, results of this study indicated to enhance the performance and mechanical strength after use these composites. Chyad F. A., (2013) investigated the influence of sintering temperature and studied the fracture strength for porcelain strengthened with zirconia. In this study, Weibull distribution function was used to evaluate the probability distribution for fracture strength. Results of this study indicated that Weibull modulus and fracture strength improved by increasing of sintering temperature and zirconia content as shown in figures (5 and 6).

Haider, Chyad, and Jaber, (2009) studied the effect of zirconia addition on mechanical properties as (indirect tensile strength and Vickers hardness) and physical properties as (apparent porosity, water absorption, linear shrinkage and bulk density) of the porcelain specimens. Different weight percentages (5,10,15,20) % of zirconia was used as an addition to the porcelain specimens formed from the composition shown in table (1). Results of this study showed that a percentage not increase (10%) for the zirconia addition enhanced the mechanical and physical properties for the porcelain specimens specifically the indirect tensile strength.

CONCLUSIONS

1. Although the investigations on influence of zirconia addition on the porcelain properties, specifically mechanical properties, were limited, it can be concluded from the investigations above that the addition of zirconia for the porcelain can be enhanced the porcelain properties by the strengthening method of brittle materials which includes the combination of crystalline materials that are capable to undergo a transformation in crystal structures when put under stresses.

2. Also the fracture strength, fracture toughness and hardness for porcelain ceramics are more influenced with zirconia content additive and sintering temperature used for it. Thus, it can be significantly benefited from zirconia addition to porcelain in the improving of many properties for it. Also further investigations are required to study other properties of porcelain with the zirconia addition.

FIGURES AND TABLES

Table 1. The composition of porcelain samples (Haider, Chyad, and Jaber, 2009).

Sample No.	Kaolin	Sand	Feldspar Potash	Calcium Carbonate
A	50%	25%	25%	–
B	80%	10%	10%	–
C	50%	40%	–	10%

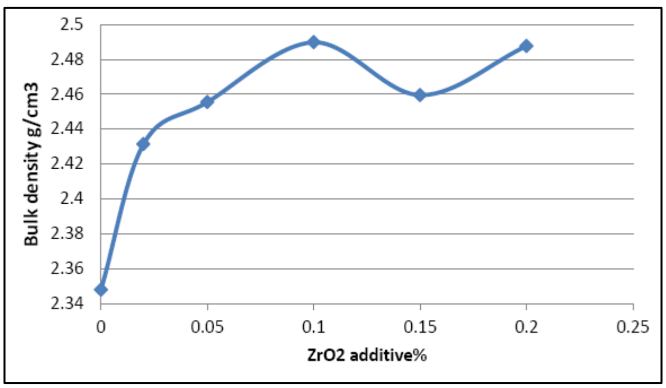

Fig.1. The zirconia content's influence on the porcelain samples' density (Saadon A.K., 2016).

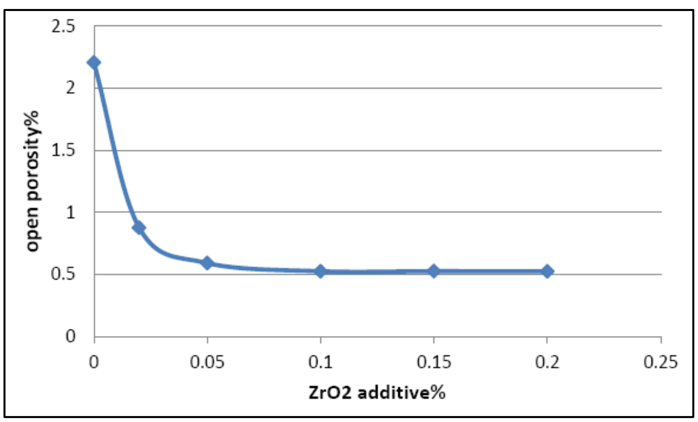

Fig.2. The zirconia content's influence on the porcelain samples' porosity (Saadon A.K., 2016).

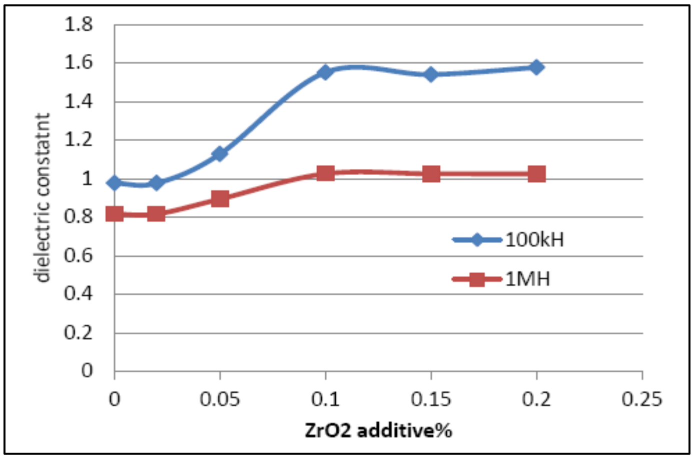

Fig.3. The zirconia content's influence on the dielectric constant of porcelain samples at (1MHz) and (100KHz) (Saadon A.K., 2016).

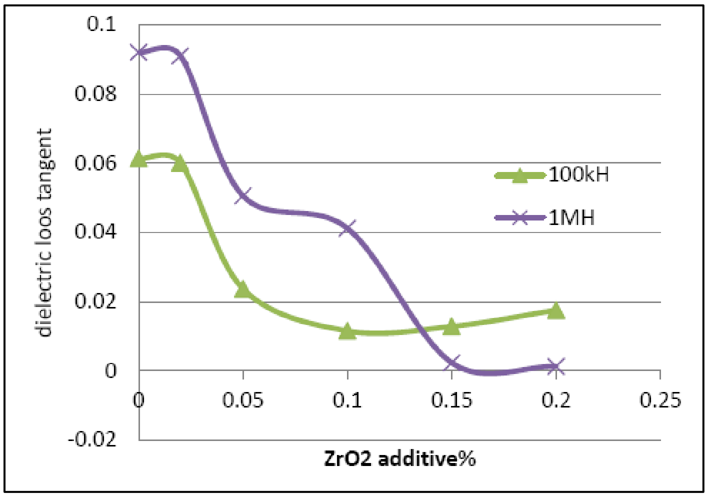

Fig.4. The zirconia content's influence on the dielectric loss tangent of porcelain samples at (1MHz) and (100KHz) (Saadon A.K., 2016).

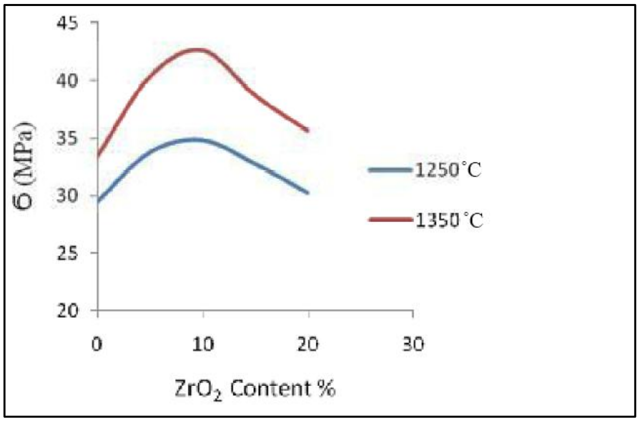

Fig.5. The influence of zirconia additive on the porcelain strength at different temperatures (Chyad F. A., 2013).

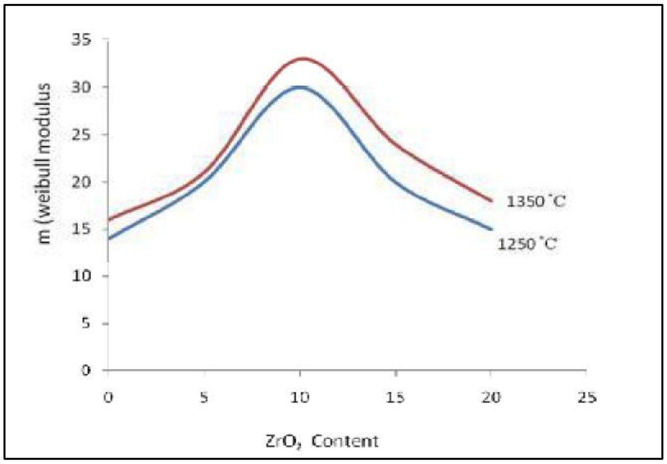

Fig.6. The influence of zirconia additive on the weibull modulus for porcelain at different temperatures (Chyad F. A., 2013).

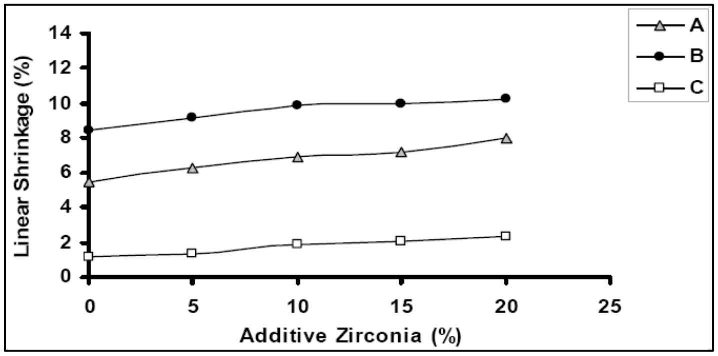

Fig.7. The influence of zirconia's content on the linear shrinkage for A, B and C porcelain specimens (Haider, Chyad, and Jaber, 2009).

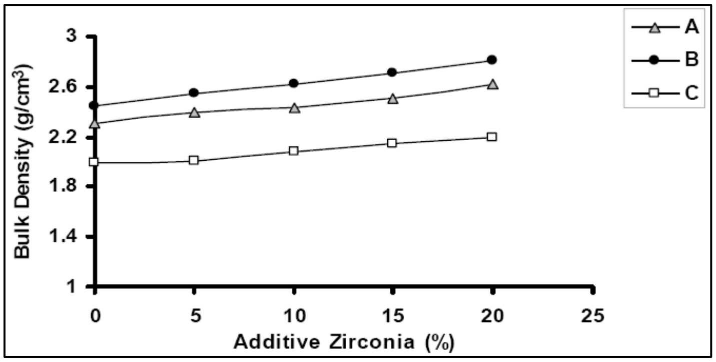

Fig.8. The influence of zirconia's content on the bulk density for A, B and C porcelain specimens (Haider, Chyad, and Jaber, 2009).

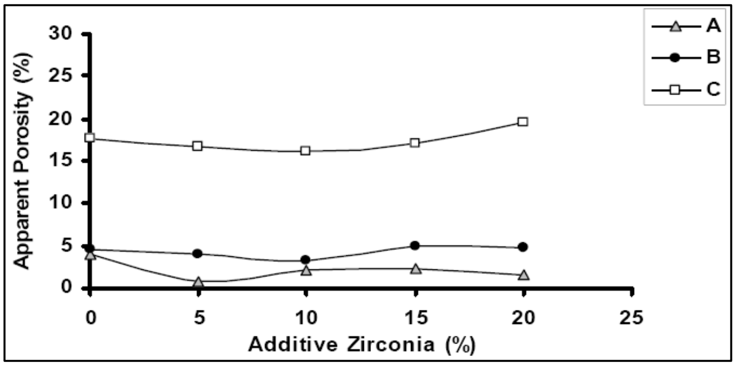

Fig.9. The influence of zirconia's content on the apparent porosity for A, B and C porcelain specimens (Haider, Chyad, and Jaber, 2009).

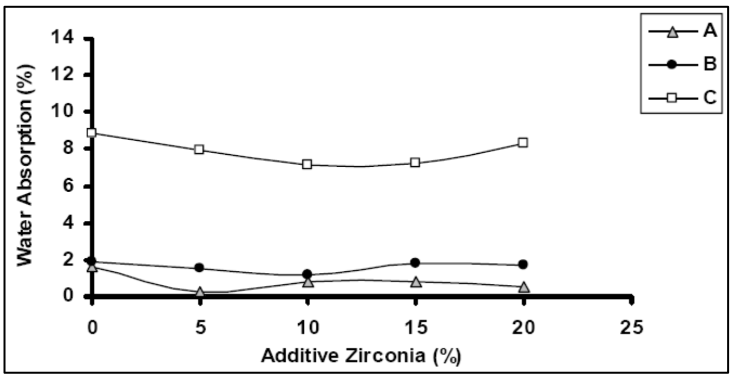

Fig.10. The influence of zirconia's content on the water absorption for A, B and C porcelain specimens (Haider, Chyad, and Jaber, 2009).

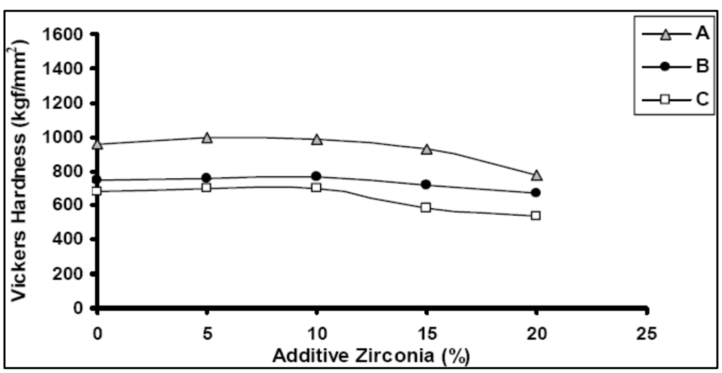

Fig.11. The influence of zirconia's content on the Vickers hardness for A, B and C porcelain specimens (Haider, Chyad, and Jaber, 2009).

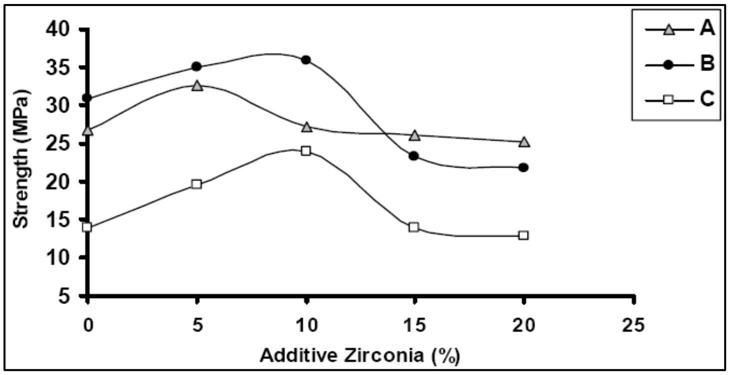

Fig.12. The influence of zirconia's content on the tensile strength for A, B and C porcelain specimens (Haider, Chyad, and Jaber, 2009).

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