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Studying the Physical and Mechanical Properties of Porcelanite: lithium metasilicate Composite as a Dental Veneer Material

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Abstract. This study is designed to prepare and evaluate a new composite material composed of Porcelanite and lithium metasilicate, mixing them in different weight percentages 20:80, 25:75, 40:60, 50:50, and 75:25, respectively, in order to develop a new composite material by a solid state reaction method, with advanced properties for physical and mechanical which can be used for dental veneer applications. Results show that the percentage of Porcelanite strongly enhances these properties for the composite, until reaching the sample with (75% Porcelanite and 25% Lithium meta silicate), which is begun to reduce. The best weight percentage from the view of physical properties, cold crushing strength, and the micro hardness, will be the 50% Porcelanite, which is suggested it to be as a good dental material used in veneer applications.

1. Introduction

The production of ceramics is one of the most ancient human industries. Pot making, for instance, is one of humankind's first inventions, and because of the durability of the ceramic products they are some of the best records of human cultural beginnings. Ceramics used for dental applications are classified depending on three factors melting point, manufacturing process and the crystal structure. The four classes of depending on melting technique: Ultra-low less than 870°C, Low between 870 to 1090°C, Medium between (1090 to 1290) °C, and the high melting at (1315 to 1370) °C. Porcelanite based dental ceramics are made with medium and high melting temperature. The classifications depend on process include traditional apply of layers, hot pressing, slip casting and machinery techniques [1].

Among all laminate veneer options, ceramic veneers have the longest in this science (Dental science), compounds of oxygen with one or more metallic or semi-metallic elements refers to primarily structure of ceramics which is in the original are referred to as nonmetallic, inorganic structures in their primarily containing [2].

The base of dental ceramics including a crystal phase and a glass phase they are termed by silica by silica tetrahedra, including main Si^{4+} ion with four O^- ions. The ordinary dental ceramic are normally virtuosos with scrubby crystallization area. Which have both covalent and ionic feature. Alumina (Al_2O_3) are crystalline ceramic used in restorative dentistry at current day one of the intense oxides ever renowned [3].

Because of the natural look and translucency as well as their strength excellent intraoral stability, wear resistance adding to their durability make ceramic used for wide range. Biocompatibility give ceramic high advantage for use in interior part of the human body [4]. Pocolanites; these are siliceous rocks, they are part the phosphorene in the western (Digme and Akashat formations respectively). are siliceous rocks, found in Iraq, are from an industrial bed of (0.5 to 1.3 m) thickness in the Safra, and Trafawi site of the Jeed formation in Al-Rutba region, western of Iraq, it is composed of opal- CT



(crystallite– tridymite crystal stratification) and are derived from biogenic amorphous opalline silica, associated with shale [5,6].

Objective of the sitting work is to predict the role of local porcelanite and how successful it will be in production a veneer ceramic material in combination with the glassy lithium metasilicate [7], [8], by studying the physical, mechanical and microstructure of the prepared composite material.

2. Experimental work:

2.1. Materials & Methods:

Different materials are used during this work, local Porcelanite and Lithium metasilicates.

Porcelanite; Iraqi Porcelanite was brought from local market with composition shown in Table1, and the x-ray analysis given in Figure below.

Table 1. Chemical analysis for porcelanite.

Materials	SiO ₂	CaO	Al ₂ O ₃	Fe ₂ O ₃
No.	72%	12%	4.8%	2.1%

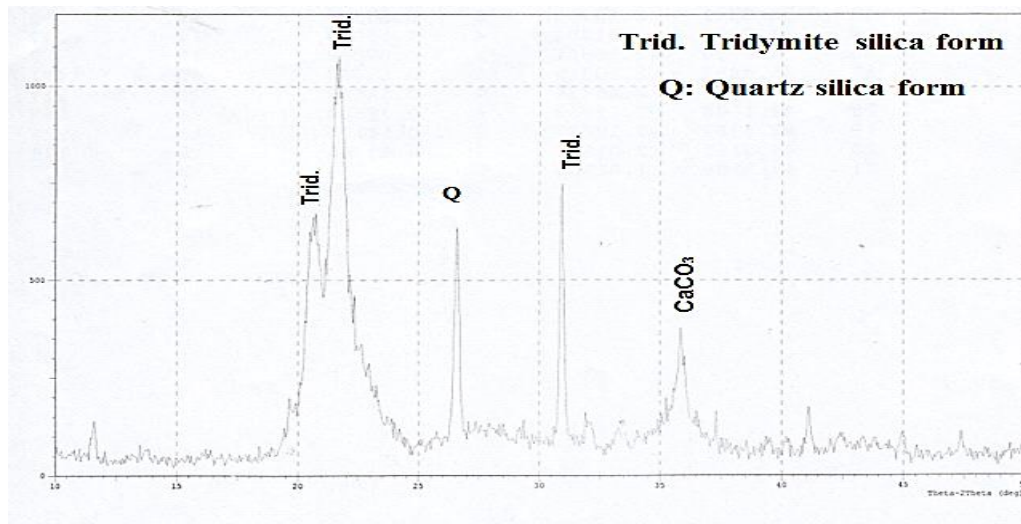


Figure1. The X-Ray diffraction pattern for the Porcelanite [6].

Lithium metasilicate; Li₂SiO₃ is prepared as given below from Silica and lithium carbonate as shown in Table 2 below.

Table 2. Chemical analysis for lithium metasilicate

Materials	SiO ₂	LiCO ₃
Percentages	50%	50%

Lithium metasilicate (Li₂SiO₃) is prepared, from lithium carbonate and silica (SiO₂), they are mixed carefully using porcelain ball mill and fired in an electrical furnace at 550°C for one hour to produce lithium metasilicate.

Various samples were prepared using three different ratios for both of Porcelanite: Lithium metasilicate, as given in Table 3 below.

Table 3. Mixing ratios of raw materials

Sample No.	Porcelanite Wt%	Lithiummetasilicate Wt%
1	20	80
2	25	75
3	40	60
4	50	50
5	75	25

Porcelanite is milled by porcelain ball mill and sieved using sieve no. (10 μ m), then mixed with the prepared lithium metasilicate in different ratios as shown in Table3, then three drops of water were added as a binder to the mixture. Samples with 1 cm in diameter were formed, under 2.5 tons pressure for 3 minutes pressing duration by the universal pressing machine. The prepared samples are dried at 150 °C for 2hrs, then sintered at 1200 °C for 2hrs and cooled slowly by keeping the samples in an oven overnight to prevent the generation of internal stresses cracks. Then the mechanical and physical properties are measured and calculated.

2.2. Physical Tests

Porosity (P), Water Absorption (WA), Bulk density for the prepared samples are measured and calculated by applying Archimedes principles, according to (C373-72) ASTM , and using the following equations [1] :

$$P = (W_s - W_d / W_s - W_n) * 100\% \quad (1)$$

$$WA = (W_s - W_d) / W_d * 100\% \quad (2)$$

$$\rho = (W_d / W_s - W_n) / p_w \quad (3)$$

Where :

W_s : the mass of the wet sample

W_d : the dry sample mass

W_n : the hang sample mass after submerged for 24 hrs

ρ_w : the density of the water which is represented 1 g/cm³

2.3. Mechanical Tests (Cold Crushing Strength (CCS) and Micro Hardness:

2.3.1. Cold Crushing Strength (CCS):

Cold crushing strength represent the amount of load that the specimen could withstand. The test was done according to EN 993-5, after sintering the sample at 1200° C for 2 hrs, the samples dimensions were measured. The hydraulic load applied on the sample steadily until the sample failed to withstand more load Figure 2.



Figure2. Cold Crushing Strength Apparatus

2.3.2. Micro hardness:

When the ceramic specimen resistance the penetrated by specified indenter, this resisting measured by hardness measurement, in ceramic hardness is a measure of resistance to penetration by a specified indenter under specified loading conditions. The deformation is not only the plastic deformation but also by compression, isolation and split. the test was carried by A Vickers hardness test which was carried out by ZwickRoell Indentec ZHV μ Micro Vickers Figure3, the procedure was done by shedding 1 kg load for 10 seconds for 7 times on different locations for 5 samples.



Figure3. ZwickRoell Indentec ZHV μ Micro Vickers

3. Results and Discussion:

3.1. Physical test:

The physical parameters (porosity, water absorption and density), were calculated using the equations 1, 2, 3 respectively and the results for the prepared samples, were shown in Figures 4,5&6 below:

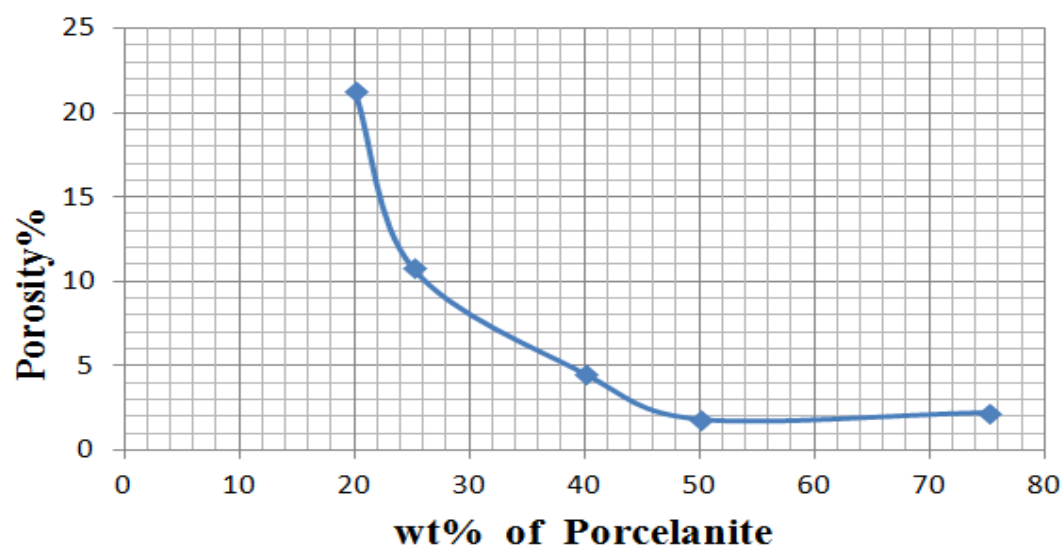


Figure 4. Porosity of Porcelanite: Lithium metasilicate instaled with various mixing ratios.

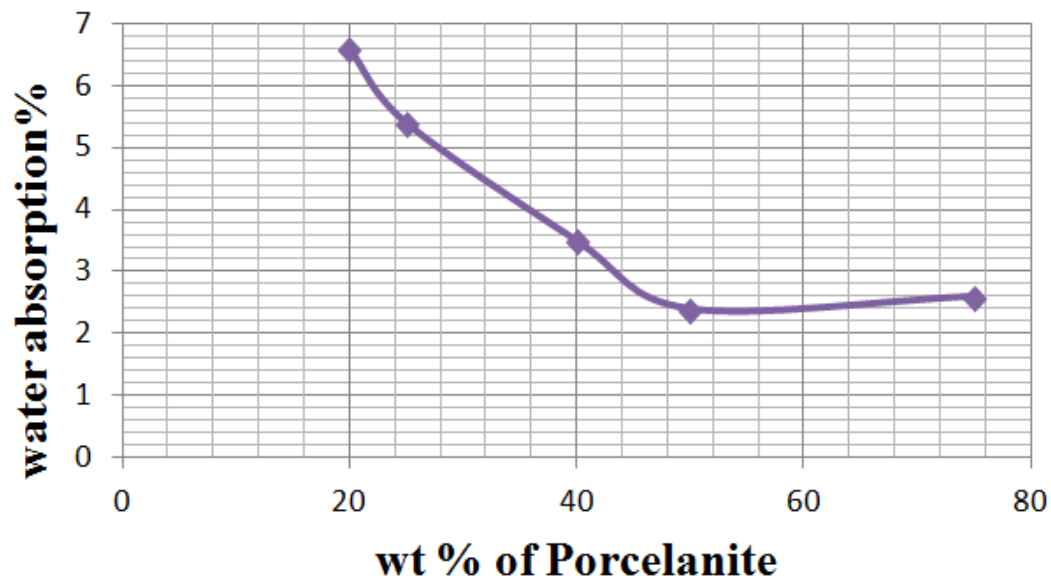


Figure 5. Water absorption of Porcelanite: Lithium metasilicate composite with different mixing ratios.

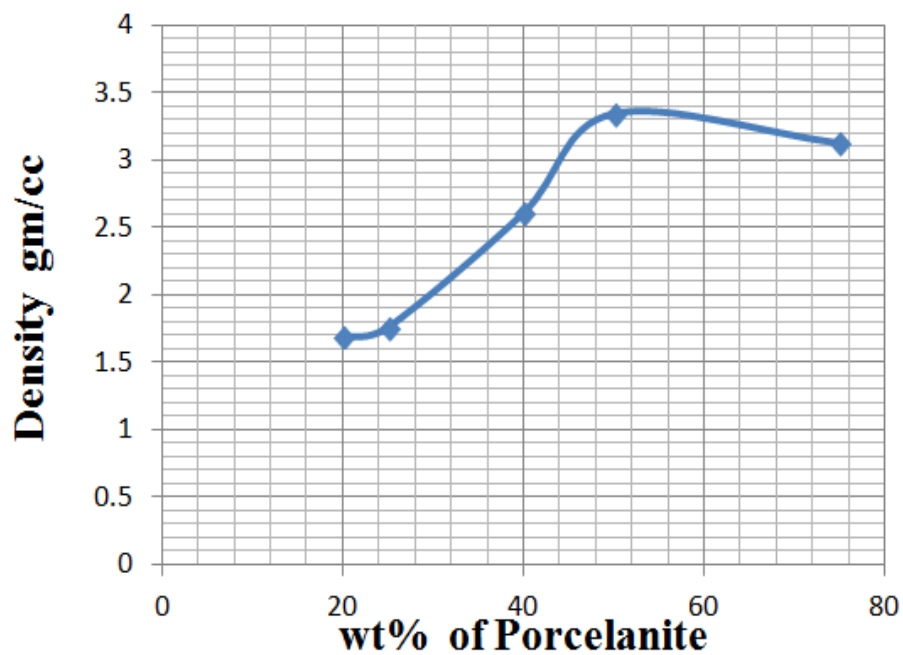


Figure 6. Density of Porcelanite: Lithium metasilicate composite with different mixing ratios

3.2. Mechanical properties:

3.2.1. Cold Crushing Strength (CCS):

The maximum listed load is taken as the crushing load. The results are shown in Figure .7 below:

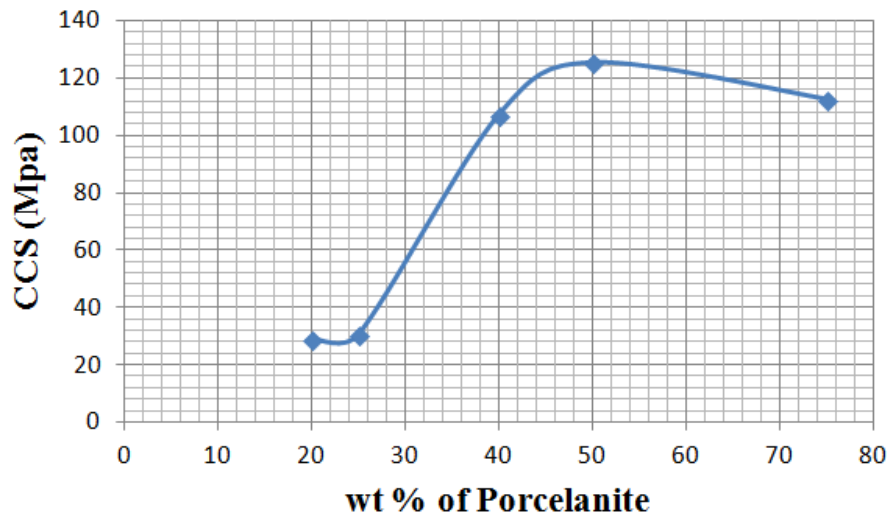


Figure 7. Cold Crushing Strength (CCR) of Porcelanite: Lithium metasilicate composite with different mixing ratios.

3.2.2. Micro hardness:

The values of measured a calculated micro hardness, is shown in Figure 8 below.

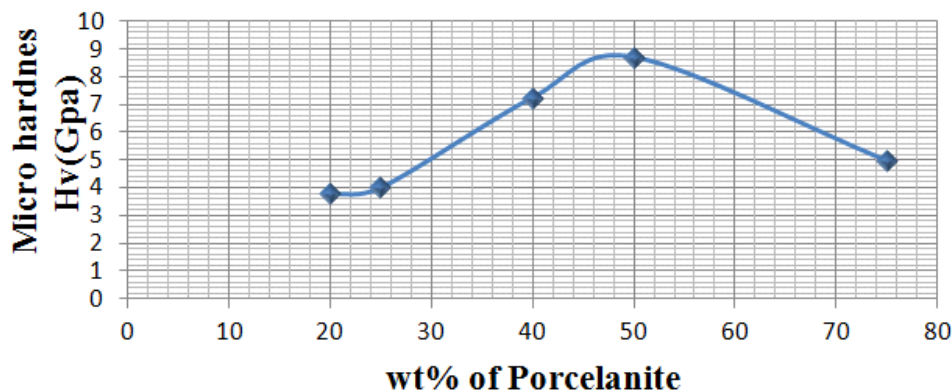


Figure 8. Micro hardness of Porcelanite: Lithium metasilicate composite with different mixing ratios.

These values indicate that the properties are enhanced using high ratio of Porcelanite, high density, low water absorption, less porosity, good crushing strength, and best hardness, until exceeding the equal percentages for each of porcelanite and lithium metasilicates, the behavior differs.

The cold crushing strength data are approved the physical data, the more percentage of Porcelanite is, more strengthen product.

Advanced mechanical properties were the great performance for dental requirements. The higher crystallinity degree is responsible in improving mechanical, unfortunately, higher crystallinity is also associated with higher opacity. ceramics, porcelanite in the present work. [9].

3.3. Scanning Electron Microscopy

The frequent method for assessment the surface between ceramic materials layeres, was shear bond strength , This method usually coupled with scanning electron microscopy (SEM) to identify the kind of failure (cohesive or interfacial), even if it can detect the impact of experimental setup factors, such us ; temperature, humidity) ,cannot detect the first stages of aging or interfacial) or to understand its mechanism and suffers from poor depth resolution.

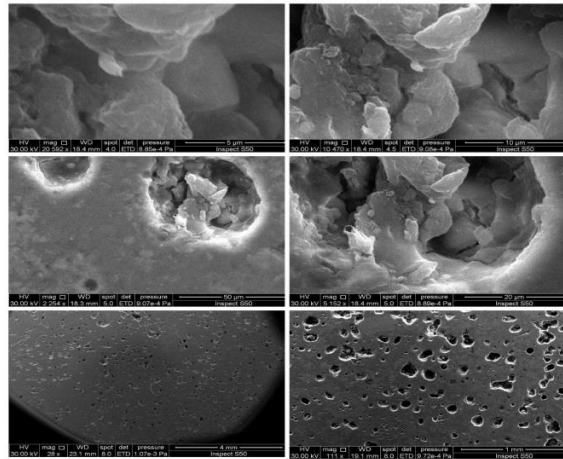


Figure 9. Scanning electron microscope for sample, 25%Porcelanite, 75%Lithium metasilicates

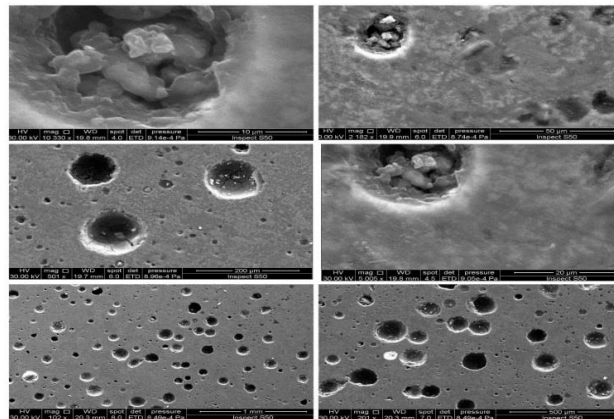


Figure 10. Scanning electron microscope for the sample 50%Porcelanite, 50%Lithium metasilicates.

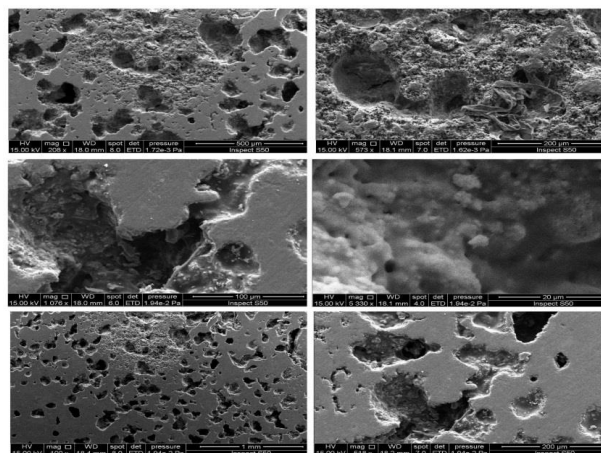


Figure11. Scanning electron microscope for sample with 75% Porcelanite, 25%Lithium metasilicates

Fault and inclusions are also found in ceramic veneer as well as pores, as shown in Figures above, cracks and inclusions are also present Figures (9,10&11) show that the defects and inclusions are limited and restricted in the sample of equal percentages, due to high percentage of porcelanite which plays a very important rule in good compaction without inclusions. Li_2SiO_3 , the differ between glass and porcelanite that the glass phase is formed during heating, which there is almost no crystal growth on the other hand the porcelanite undergo a grain growth during heating, which compensated by glass phase of lithium metasilicates.

4. Conclusions:

It was a bold step to prepare a dental ceramic material from abundant, and cheap materials, by using simple manufacturing techniques, with a good property. Finally, was concluded that the physical and mechanical properties are considered shown in Table .4 below.

Table4. Properties of the prepared composite materials.

Porcelanite wt%	Density g/cc	Porosity %	Water absorption %	CCS (Mpa)	Micro hardness Hv (Gpa)
20	1.69	21.3	6.6	28.5	3.78
25	1.76	10.3	5.4	30.4	4.01
40	2.61	4.5	3.5	107.1	7.25
50	3.35	1.8	2.4	115.5	8.69
75	3.13	2.2	2.6	112.5	4.97

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