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RESEARCH ARTICLE – CHEMISTRY

Preparation and Characterization of $CaZrO_3$ as a Bone Cement

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Abstract

The bio ceramic constant of zirconium dioxide and calcium oxide with a weight ratio of 1:1. It was prepared using a ceramic grinder with hardened ceramic balls for 10 continuous hours at a rotational speed of 350 rpm. The resulting powder was then collected and pressed into a mold with a pressing capacity of 5 tons, then sintering process was performed at a temperature of 850oC for 4 hours the sintering samples of calcium zirconate subjected to milling for 24 hrs to obtain a very fine powder on the at nano scale. Structural examinations of Calcium Zirconate (CaZrO3)powder were carried out by utilizing such as X-ray diffraction and scanning electron microscopy SEM, and Raman spectrum. A mixture of powder was prepared in the form of a paste by adding 30% of polylactic acid PLA for the purpose of making ceramic cement. It can be stored in ampoules for use in treating cracks in bones. The results of the hardness and toughness test of bone cement showed that the percentage of the binding material (polymer) is 30%.

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Keywords: Calcium Zirconate bio ceramic, Nano scale, PLA and ceramic cement.

1. Introduction

Bio ceramics are considered promising biomaterials in bone and dental prosthetic applications. Many researchers have been interested in this field, especially in the last decades of this century, as they are available in nature and their compounds are included in bone structures, in addition to their mechanical and biological properties that are compatible with the tissues of the living human. [1]. At high oxygen pressure, it acts as an electronic conductor and an ion conductor. When the material is doped with oxides like alumina Al_2O_3, yttrium Y, or magnesia (mg), or with a tiny excess of calcium Ca or zirconia ZrO_2, the ion conductivity rises [2, 3]. Thus, calcium zirconate ($CaZrO_3$) has been used in sensors that track hydrogen H, oxygen O, and humidity. Because of its high dielectric constant and low temperature coefficient, as well as its low loss tangent, it can also be utilized in ceramic capacitors [4, 5]. Owing to its elevated melting point of 2368°C, superior chemical inertness, and commendable resistance to thermal shock, it has been examined and employed as a ceramic substance for elevated temperature uses.

Polymeric biomaterials called bone cements are utilized to fix articular prostheses. These materials are intended to convey complicated mechanical loads in addition to serving as fillers between the metallic prosthesis and the bone. Traditional bone cements are made mostly of methyl methacrylate monomer, which is a liquid component. As well as a solid portion made mostly of poly(methyl methacrylate). Despite being widely utilized in modern orthopedics, they have poor bioactivity, high shrinkage, high polymerization exotherms, and a high residual monomer concentration. These characteristics additionally stem in poor mechanical performance, which adds to the aseptic loosening of the implant by causing chemical and thermal necrosis of the surrounding tissue [6,7,8] One of the most fascinating and fulfilling fields of materials science research is medical application.

Owing to these drawbacks, new bone cement formulations incorporate bioactive ceramics to increase their biocompatibility as well as low toxicity activators and low heat polymerization monomers Orthopedic nails and screws, dental filling materials, orthodontic wires, pacemakers, heart valves, pacemakers, breast implants, fracture fixation plates, and complete joint replacement prostheses are a few examples from everyday life. Ageing populations and the democratization of high-risk sports have contributed to an increase in bone-related illnesses and fractures in recent years, which call for implant therapy. [9, 10, 11]. Cements operate as a load distributor between the artificial implant and the bone by creating a mechanical interlock between the metallic prosthesis and the bone [12, 13]. Ceramic materials are used as prosthetic materials to replace broken bones or teeth. They are also distinguished by their light weight and high temperature resistance. Its qualities have piqued the interest of numerous experts in this sector who want to use it for further industrial and medicinal applications [14]. From previous studies in this field, researchers have studied H. Chul, C. at el. [14]. The mixed ionic and electronic. Conductivity of $CaZrO_3$ with action nonstoichiometric and oxygen partial pressure and C. Yuan, at el. [12]. Investigation into the use of $CaZrO_3$ as a face coat material in the investment casting of TiAl alloys and J.Odah, at el. [15], synthesis and characterization of ceramic system beta tri-calcium phosphate used in teeth and bones substitutions. This research aims to develop a bio-ceramic composite that can be used in medical applications such as bone and dental prosthetics or as bone cement

.2. Materials Used and Method of Work

In this work, bio-ceramic cement was prepared using the method of preparing the compound calcium zirconite $CaZrO_3$ in the form of a fine powder that reaches the nano level in granular size .A ball milling method with very hard balls made of high solid alumina was used, and the balls were placed with 50 grams of calcium oxide powder. With 50 grams of zirconium dioxide, a liquid of 100 ml of distilled water was placed in the container Fig.1 (a), and then the mill was operated for 10 hrs, after which the powder was dried and pressed into a mold with load applied of 5 tons, after which calcining was performed at a temperature of 850 oC for 4 hrs after this step, structural tests were conducted on the compound to ensure the formation of calcium zirconate powder. After ensuring the powder was formed, it was ground again in the same grinder, but without water, for 24 hrs, keeping the resulting temperature at 25oC. After the process is completed to obtain the powder close to nano as show in fig1 (b), it is mixed with the medical polymeric PLA at a rate of 30% and the mixture is kept in ampoules prepared for that purpose for the purpose of injecting them into the damaged areas in the bones of the organism. The process of preparing the bone cement paste is to take a weight ratio of 30% of the binding material (polymer) with a ratio of 70% of the ceramic powder prepared in the above step. These selected ratios are the result of an experiment where we obtained a cohesive, complete consistency and fast-hardening paste where ratios of the binding material from 5% to 30% were used and the best result obtained was the ratio of 30%, so this ratio was adopted for the binding material for the ceramic powder.

Fig.1 (a): Experimental part of Synthesis Solution $CaZrO_3$ Cement bone

Fig.1 (b): white powder of $CaZrO_3$ and PLA

3. Results and discussion

In this section, the research will be discussed through interpretations of X-ray diffraction (Shimadzu XRD-6000) and scanning electron microscopy SEM (Jeol JSM-6335F), in addition to examining energy dispersive spectrometry EDX [16, 17] .

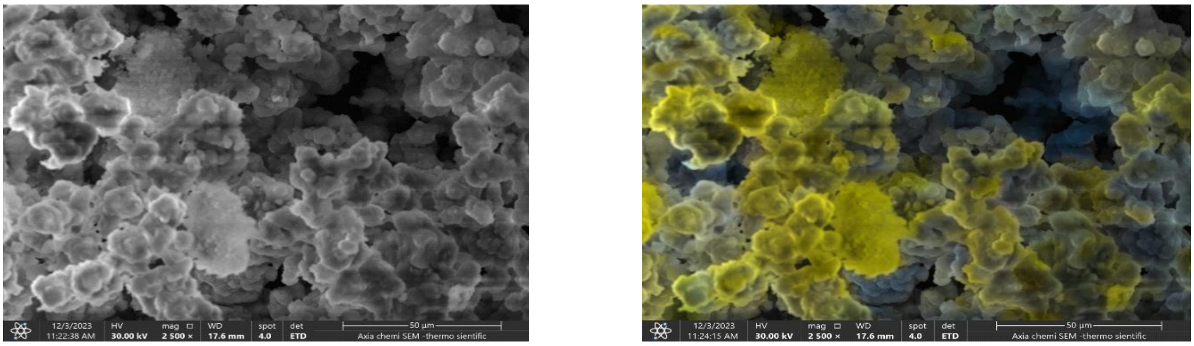

Fig 2: SEM- Image of $ZrCaO_3$ Cement bone

Table 1. EDX- Test of CaZrO3 Cement bone

C	**16.4**	**0.2**	**8.7**	**0.1**
O	67.9	0.5	47.8	0.4
Ca	8.7	0.0	15.3	0.1
Zr	7.0	0.2	28.2	0.8

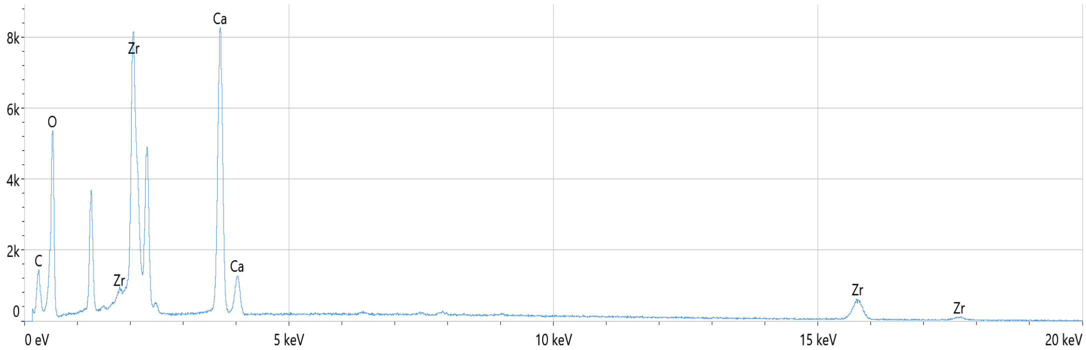

Fig.3: shows the results of EDS spectrum of ZrCaO3 Cement bone

The table 1 shows the values of the weight percentages of the materials involved in the preparation. It was found that the percentage of calcium element is 15.3 while the zirconium element is approximately 28.2. This indicates that the preparation process is accurate as the molecular color of zirconium oxide is more than the molecular weight of calcium oxide. It is clear from the graph in fig3 that the highest peak belongs to the element zirconium. The presence of the Carbon element is the result of its use in coating the powder for the purpose of conducting the examination. It is an outer layer that does not represent impurities within the compound, as shown in yellow in the picture in fig2.

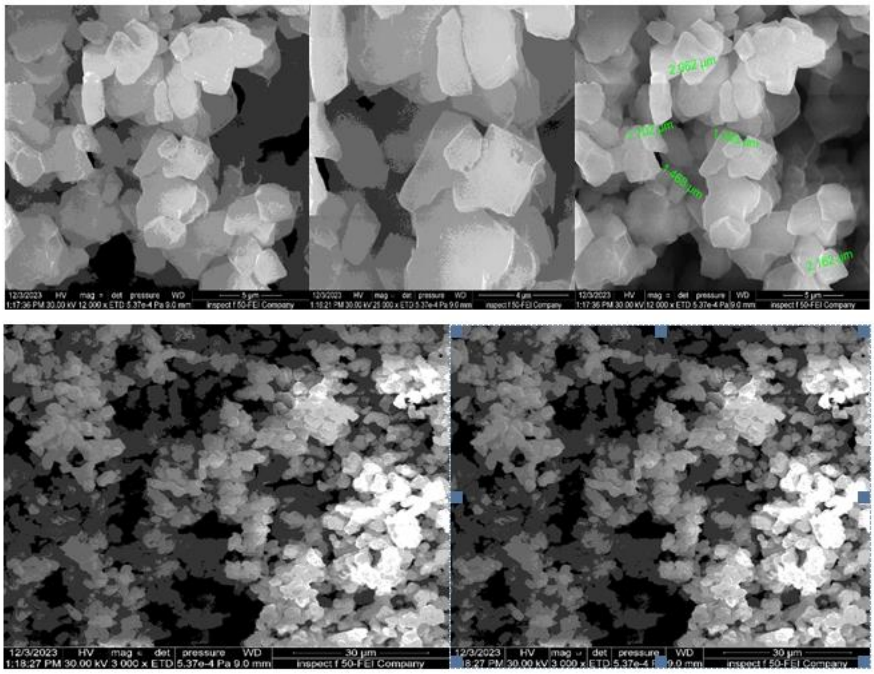

Fig. 4. SEM- images of CaZrO3 Cement bone

The figure 4 shows the results of the scanning electron microscope examination. The shapes show the formation of cube-like grains of the compound, which show clear regularity due to the crystalline fusion occurring between calcium ions and zirconium ions. The microscope images also show the dimensions of these granules at a rate of 2 microns to 1 micron, and this is evidence that the powder approaches the Nano scale range agree with [17,18].

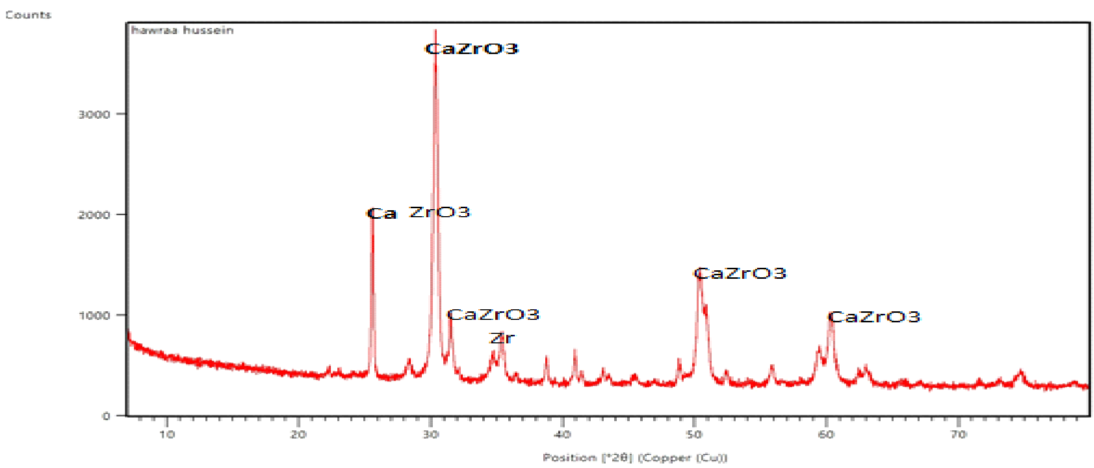

Fig 5. XRD pattern of $CaZrO_3$ Cement bone

The figure 5 shows an examination of the X-ray diffraction of the compound at temperatures of 850 ^{0}C, as well as when grinding for 10 continuous hours. The figure shows the formation of a crystalline calcium zirconite $CaZrO_3$ ceramic compound.

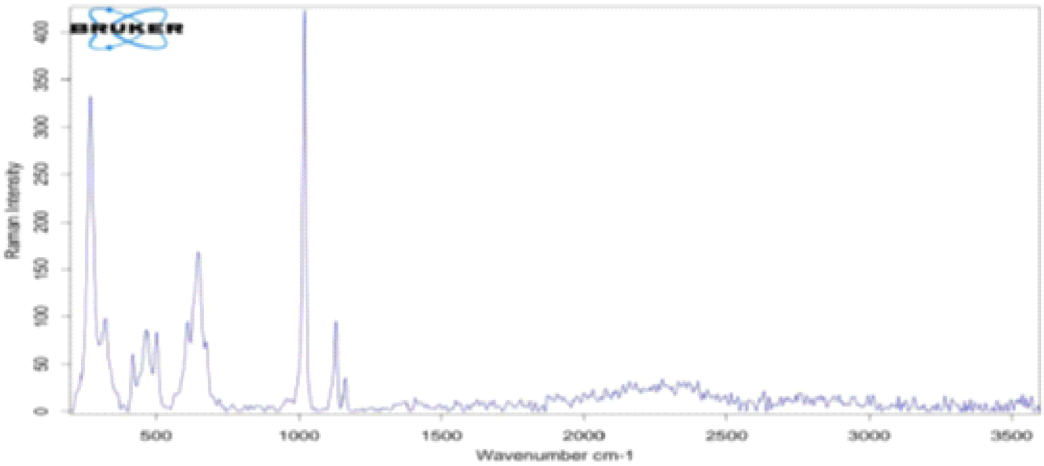

Fig. 6. Raman Spectrum of $CaZrO_3$ Cement bone

Fig. 6. The figure shows a Raman Shift test. Its purpose is to identify the compounds and molecules involved in the formation of the calcium zirconite compound. The results of the examination show the association of the calcium molecule with the zirconium molecule agree with [19, 20].

4. Conclusions

The results of this work can be summarized as follows: The preparation using ball milling method has proven to be very effective in producing a sufficient amount of ceramic powder, unlike other preparation methods, which are economical, inexpensive, and short on effort and equipment. Also, one of the important conclusions in this work is that the selected percentage of the binding material (polymer) is a percentage that has proven successful in forming bone ceramic cement paste. Through this percentage, which is 30%, bone cement has gained high hardness close to the hardness of human bone. One of the important conclusions in this work is the structural examinations that were conducted on the ceramic powder, where the obtained results explained the conformity of the preparation components and their molecular bonding between calcium oxide and zirconium oxide through X-ray diffraction examination, while the energy dispersive spectroscopy examination associated with the scanning electron microscope showed the conformity of the weight ratios used in the preparation, in addition to examining the electron microscope images, which showed the values of the grain size of the ceramic powder used in the manufacture of bone cement.

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