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Biomechanical Properties of PMMA/ Bio glass Ceramic

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Abstract:

In this study, nanocomposites were prepared by reinforcing the PMMA polymer with weight ratios from Bio-glass ceramic and these ratios were 0%, 1%, 2%, 3% and 4%, respectively. Samples were obtained using the manual liquid mixing method. How many mechanical tests were carried out (hardness, fatigue)? The results obtained showed a significant improvement in the stiffness and fatigue life values of the material after reinforcement.

Keyword: PMMA, Glass Bio-Ceramic, Hardness, and Fatigue.

Introduction

Bio - glass ceramics are not chemically different from bone material. It also provides the physiological needs of culture in the human body. The formation of chemical bonds at the interface between the host tissue and the implant gives the meaning of vital activity [1]. Examples of bio - glass ceramics are glass containing plaque flour apatite and hydroxyl apatite crystals [2] .The advancement of the biologically active apatite layer made the biologically active glass chemically bond to both hard and soft tissues [3]. Because of the possible weak interface and porous structure between the ceramic and polymer phase, the chemical properties of bioactive glass compounds are a source of concern [4]. There are common chemically or Structurally between the bio - active materials and the inorganic minerals in the bone, the hydroxyapatite powder sintering process is the most straightforward method for producing bio - active glass ceramics. However, this method has disadvantages which are the non-strong mechanical properties of the sintered product and the lack of thermal stability of the hydroxyapatite. The vitality of the glasses indicates the presence of the hydroxyapatite layer, where as a result of the interaction of the glass and the environment of the body this layer is formed. The amount of Young's modulus is approximately 35 GPa For the bio - active glasses, as a result the implants of these materials have more stiffer than the cortical bone (15 – 25 GPa) . One of the disadvantages of bio - active glasses is twice Its mechanical properties. The fracture toughness of the cortical bone (2.2 – 5.7 MN $/m^{3/2}$)is greater than the fracture toughness of bio - active glass ceramics.Therefore, the bio - active glass ceramic property must be developed for implant applications. The purpose of developing bio - active glass ceramics is to create an implant that has higher mechanical properties compared to glass. The process used to produce bio - active glass ceramics is the use of the traditional method of casting, following a process of heat treatment of crystallization and pressing of powder from the original stage following the processes of sintering and crystallization [5]. Bio - active glass ceramics have a basic crystalline phase, which is apatite, which crystallizes evenly throughout the material.Most of the components of bio - glass ceramics are identical to the components of bio - active glass but with Na_2O less and

P_2O_5 A little higher [6] . The fields of modern life have become indispensable for polymer products and parts. As in other fields, we find their use increasing also in the field of medicine. Polymers have very necessary physic mechanical properties, as they are distinguished by not damaging the tissues of the body and this made them an indispensable material in Manufacture of instruments, medical device parts, syringes, laboratory equipment, catheters, probes, tires and lenses [7]. PMMA is commonly called acrylic resin. It is a polymer composed of ester of poly (meth acrylic acid) and methyl methacrylate (MMA) chemically. The PMMA polymer manufacturing process is done by the radical polymerization of MMA, and coordination and anionic polymerizations are also available. Because PMMA is lightweight and rigid, it is used in a wide variety of applications, including screens, optical materials, and automobiles, displays, electronics, as well as other industries [8].Fatigue is the breakdown that occurs as a result of repeatedly applying stress to it. These stresses are not constant as they vary from minimum to maximum on a regular basis. The fatigue test measures the number of cycles required for a substance to break down [9].

In 2007 B. R. K. Blackman et al.,They explained that the introduction of nano - silica particles into the epoxy polymer results in an increase in the initial stiffness as it was measured by the fracture stiffness. A significant improvement in the cyclic fatigue behavior of the epoxy polymer was also observed [10] .

In 2016 Mohammadreza Eftekhari, Ali Fatemi ,In this study, they examined the effect of fatigue behavior of injection molded polymer compounds filled with talc and short circuits by repeated rotation through controlled fatigue tests of load at low temperatures and several stress ratios[11] .

In 2001 F Ram Steiner , T Armrest , Each worked on a study of crack spreading, applied frequency, the effect of sample shape and measurement with the amplitude of static or increased stress intensity[12] .

Theoretical part

Hardness is the resistance that a material exhibits to deformation that results from corrosive forces or the deepening of the surface. It is a mechanical test of the properties of materials used in engineering design, development of composite materials and structural analysis. Hardness is defined as the material's resistance to permanent state deformation such as the depth of implantation, abrasion and abrasion. Basically, the importance of the hardness test is related to the relationship between the hardness and other properties of the material. An accurate hardness device is used to measure the hardness of all samples.Vickers hardness is calculated by the following equation [13] .

$$HV = \frac{2F\sin\frac{136^\circ}{2}}{dA = d^2} \ldots\ldots (1)$$

Where:

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F: applied load in kg .

d: the arithmetic mean of the two diameters d1 and d2 in mm .

As for the fatigue equations, we apply the following [14]

$$\sigma = \frac{My}{I_x} \ldots .$$

M = W L ………………………..(4)

y = $\frac{4}{3\pi}\ R \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots$ (5)

Where:

$\sigma\ \ is\ the\ st$

M : Bending moment

W: Load

g = 9.8 $\frac{m}{s^2}$

L = length of sample

L = 0.03 m,R = 0.005 m

Experimental

In this work, Bio-glass ceramic powder was prepared by the method of powder technology and effective mechanical mixing technique. The powders of silica oxide SiO_2, calcium oxide CaO, alumina oxide Al_2O_3, and magnesium oxide MgO were mixed with oxides Na_2O and P_2O_4 in proportions that mixed the powders with each other in weight proportions.The sample was prepared by mixing the polymer powder (PMMA) with chloroform in a plastic container, mixing well and quickly due to the rapid evaporation of the chloroform, then pouring it into the special mold and placing it on a moderate surface and leaving the chloroform material to evaporate and get the pure polymer PMMA. The nanocomposites were mixed with specific weights of polymer and bio-ceramic glass, then the solvent was added and mixed well at room temperature, then poured into the molds for each test to be conducted on the material. Then the samples were left for two weeks. After that, the structural and mechanical tests were performed, including fatigue and hardness.

Results and Discussion

Take a hardness test with the Vickers device. Through the table 1 and the figure 1, we notice a significant improvement in the hardness of the nanocomposites when compared with the pure sample. As the continuous increase in Bio-glass ceramic powder leads to the formation of a

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lattice structure that helps to improve the hardness of nanocomposites that have strong ionic bonding between atoms. This is consistent with the results obtained [15].

Table 1 : Vickers hardness values

Samples Code	Hardness MPa
0% glass ceramic	54
1% glass ceramic	72
2% glass ceramic	89
3% glass ceramic	108
4% glass ceramic	132

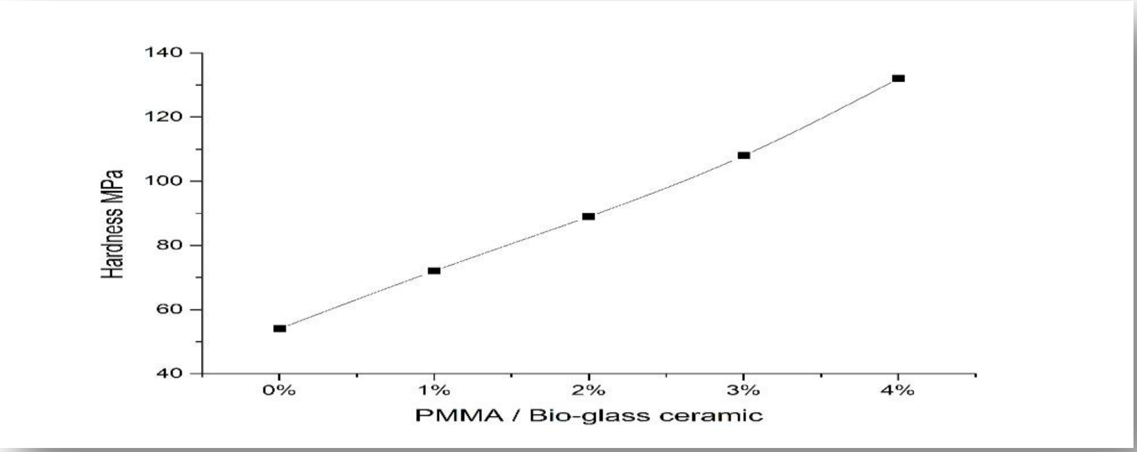

Figure 1 : Values for both pure and nanocomposite - Vickers hardness

The following results and forms of fatigue testing for pure samples and samples fortified with Bio-glass ceramic powder in weight ratios of 1%, 2%, 3% and 4%:

Table 2: stress & Cycles of 0% bio glass

Mass	Time	Cycles	Stress
10	96	384000	12×10^6
8	130	600000	10×10^6
6	225	900000	7×10^6
4	345	1380000	5×10^6
2	432	1728000	2×10^6

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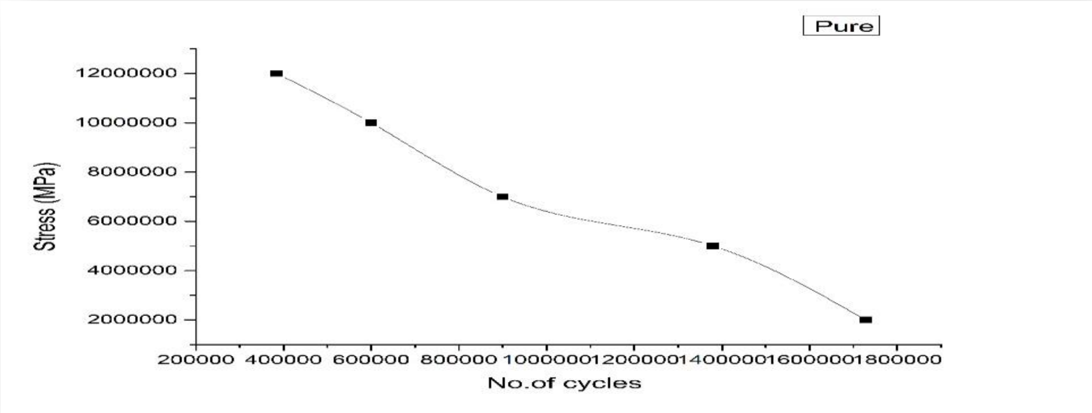

Fig. 2: **: stress & Cycles of 0% bio glass**

Table 3: stress& Cycles of 1% bio glass

Mass	Time	Cycles	Stress
10	128	7.28×10^5	12×10^6
8	194	7.76×10^5	10×10^6
6	272	10.88×10^5	7×10^6
4	376	1.5×10^6	5×10^6
2.7	458	1.832×10^6	3×10^6
2.7	540	21.6×10^6	3×10^6
2.7	540	21.6×10^6	3×10^6

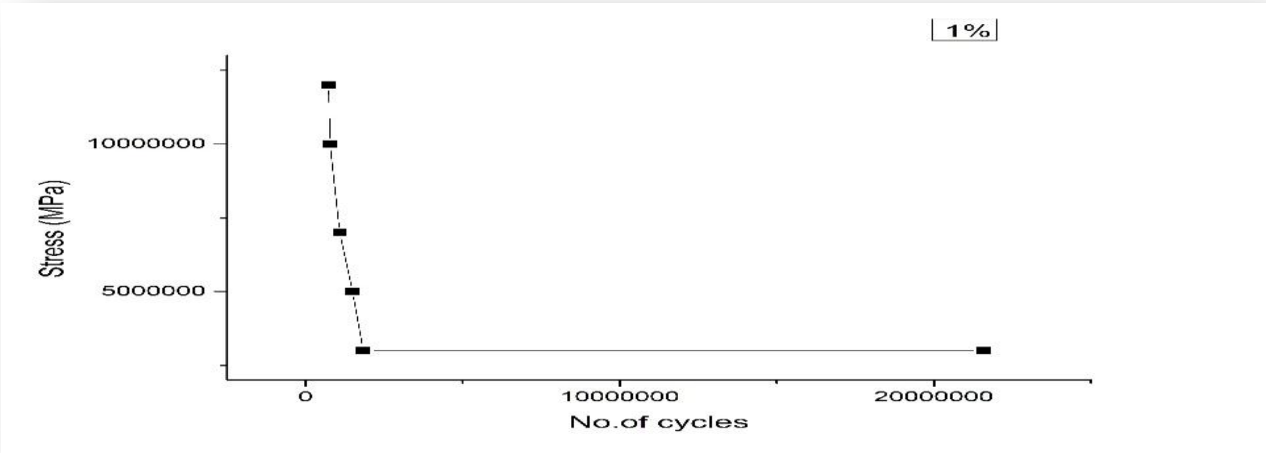

Figure 3: stress & Cycles of 1% bio glass

Table 4 : stress & Cycles of 2% bio glass

Mass	Time	Cycles	Stress
10	220	8.8×10^5	12×10^6

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8	**268**	**10.72×10^5**	**10×10^6**
6	**310**	**12.4×10^5**	**7×10^6**
4	**412**	**16.48×10^5**	**5×10^6**
3.2	**487**	**19.48×10^5**	**4×10^6**
3.2	**540**	**21.6×10^5**	**4×10^6**
3.2	**540**	**21.6×10^5**	**4×10^6**

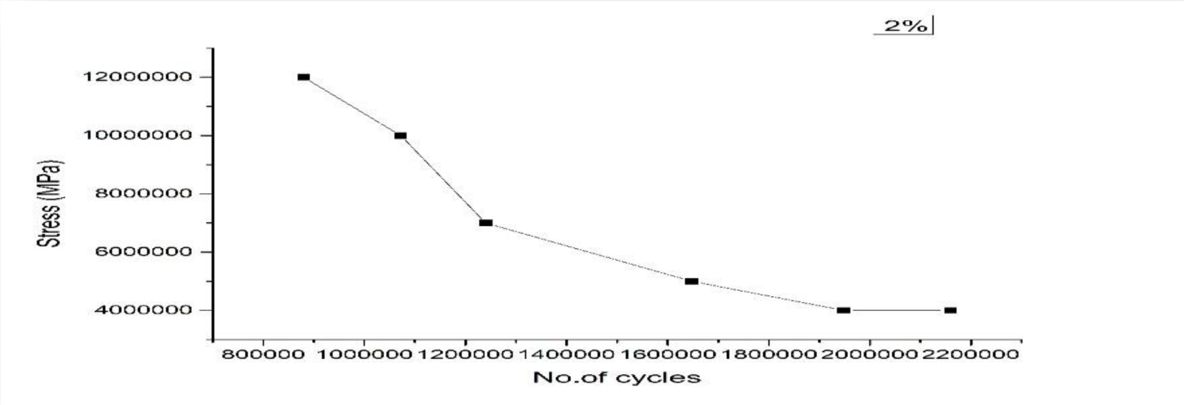

Fig.4: stress & Cycles of 2% bio glass

Table5 : stress & Cycles of 3% bio glass

Mass	Time	Cycles	Stress
10	**234**	**9.36×10^5**	**12×10^6**
8	**299**	**11.76×10^5**	**10×10^6**
6	**337**	**13.48×10^5**	**7×10^6**
4	**458**	**18.32×10^5**	**5×10^6**
3.6	**510**	**20.40×10^5**	**4×10^6**
3.6	**540**	**21.6×10^5**	**4×10^6**
3.6	**540**	**21.6×10^5**	**4×10^6**

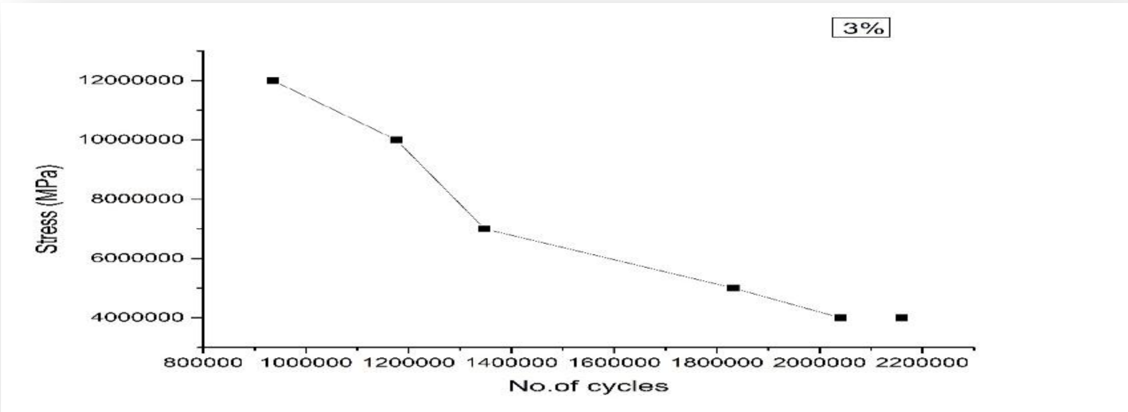

Figure 5: : stress & Cycles of 3% bio glass

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Table 6: stress & Cycles of 4% bio glass

Mass	Time	Cycles	Stress
10	248	9.92×10^5	12×10^6
8	342	13.68×10^5	10×10^6
6	388	15.52×10^5	7×10^6
5	517	20.68×10^5	6×10^6
4.4	530	21.2×10^5	5×10^6
4.4	540	21.6×10^5	5×10^6
4.4	540	21.6×10^5	5×10^6

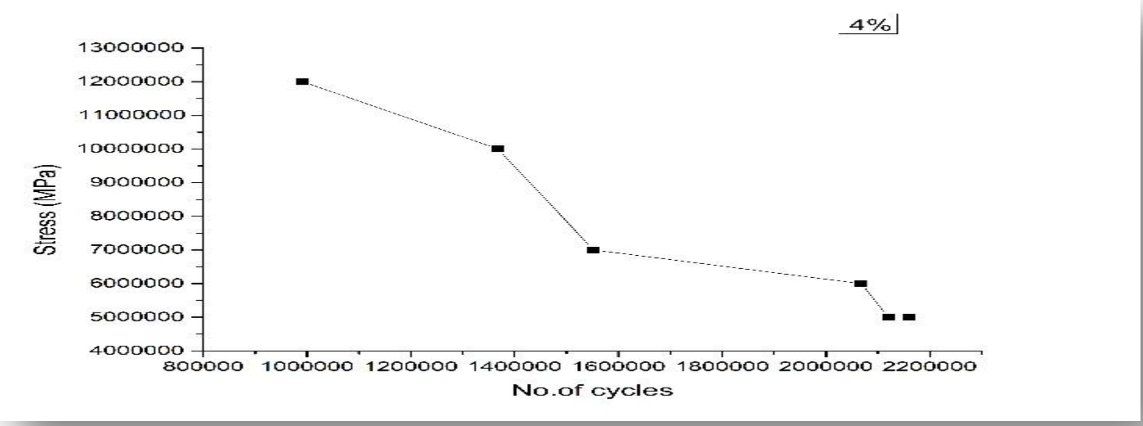

Figure 6: stress & Cycles of 4% bio glass

The material fatigue properties are described by using the fatigue curve (S-N) which is represented by the cyclic stress and the number of cycles of failure. Most of the S-N curves generally slope down from the top, i.e. from the top left to the bottom right. Whereas, high-level stresses have the fewest number of cycles of failure when compared to low-level stresses. And there is a limit in which the substance, no matter how often the stress on it, will not get tired, and it is called the endurance limit. The endurance limit represents a stress level below which the material does not fail. If the applied stress is less than the material tolerance limit, then it is said that the structure has infinite life as shown in Figures 3, 4, 5 and 6. We notice an improvement in the fatigue life of the reinforced material in Figures 3, 4, 5 and 6. The stress distribution process is affected by the spaces present in the material. The less the material contains voids in the geometric distribution, the more the stress distribution process increases. And since the unsupported core material shown in Figure 2 is most likely to have a relatively high content for such spaces, the ability of the material to distribute stresses is relatively simple and thus has a lifespan. Fatigue will be relatively short and this matches the results of [16] .

Conclusion:

Through the hardness and fatigue tests, Table 1 shows an increase in the hardness values when increasing the weight ratios of Bio-glass ceramic powder. And through the fatigue test, we notice from Figures 3, 4, 5 and 6 the appearance of the stress limit in the fatigue curve of the nanocomposite.

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