Mechanical Reliability of Bio-Composites from Bovine teeth

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Introduction:

The scope behind this work is to prepare a new cheap composite for application in the manufacture of dental implants and bone replacement. Successful performance of prosthesis require their good attachments and bonding with the body tissues and the osseointegration. Thus, orthopedic implants for bone and joint replacement must be firmly fixed and incorporated within the host bone. Two different approaches are used for purpose [1]: the first is to use porous-surface implants in which bone ingrowth into the surface porosity may take place and the second is to use ceramics or glass ceramics such as Bioglass that have controlled surface reactivity that allows bonding to take place. However, since these materials have relatively poor mechanical properties, their use in functional implants has so far been restricted. Thus, two different materials: Hydroxyapatite and a commercial type of Bioglass; one representing each of these approaches, are mixed with Plaster of Paris to form a composite, and their compression strength and Young's modulus are compared.

Materials:

Hydroxyapatite: In this study, HA extracted from bovine teeth is used (BHA). However, the method of preparation should be reviewed carefully in order to inhibit the transmission of infectious diseases like Creutzfeldt–Jakob disease (CJD) and bovine spongiform encephalopathy (BSE) [2]. The teeth samples were cleaned by boiling. The raw impurities remaining were shaved and then irrigated with a brush under running water. It was then boiled in distilled water for 30 minutes. This process was repeated for at least three times, till the samples turned white and clean. The samples were then dried in the air for 3 days, and then they were calcined in a muffle furnace at 735 ^{0}C using a heating rate of 7 ^{0}C/ min and left at this temperature for an hour. After cooling, the samples were sintered again to 1150 ^{0}C using the same heating rate and again left for 1 hour at this temperature. The teeth were then milled and stirred in distilled water. This last process was repeated till the pH of the water was unaffected by the produced powder [3].

Bioglass: For the Bioglass, porcelain dental implants were purchased from the market. It was considered the highest rank in the Egyptian market for dental implants. The samples were crushed and calcined at 1150 ^{0}C before use

Plaster of Paris (PP): Calcium Sulphate Hemihydrates ($CaSO_4$. ½ H_2O) was purchased from ***El Nasr Pharmaceutical Chemical Company***, and used as received.

Characterization of Materials:

Sieve analysis was conducted on the three different component after they have been milled prior to their compaction (Figure 1) and it was found that they have nearly matching sizes. The specific gravity of the three materials were determined using the pycnometer and are shown in **Error! Reference source not found.**. Moreover, their surface area and pore size were determined by the BET analysis (SA 3100 Surface Area and Pore Size Analyzer, Beckman Coulter). The results are shown in **Error! Reference source not found.** and Figure 2. It is seen that the PP and the BHA have deep pores with a diameter larger than 50 nm, while the Bioglass powder showed a smaller surface area with nearly no porosity.

The elemental composition of the BHA and the Bioglass samples were determined using the EDX analysis. It was found that the BHA is mainly composed of P and Ca, with some presence of Mg and K. The analysis of the Bioglass sample indicated that it consisted mainly of Si with the existence of K and Al and some traces of Na and Ca.

The XRD analysis was conducted using Maxima Shimadzu XRD 7000. On comparing the results with the Crystallography Open Database (COD) it was found that the BHA is identical to the Hydroxyapatite pattern (Entry 96-900-3549) and the Bioglass is identical to the quartz pattern (Entry 96-900-9667).

Table 1 Physical properties of the materials used.

	PP	BHA	Bioglass
Specific gravity	2.72	2.36	2.97
Surface area (m^2/g)	2.343	1.666	0.245
Pore volume (ml/g)	0.0367	0.0178	0.0020

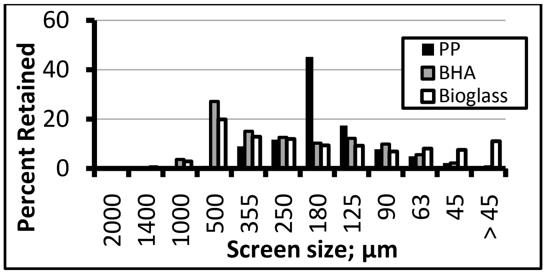

Figure 1 Sieve analysis for the three components.

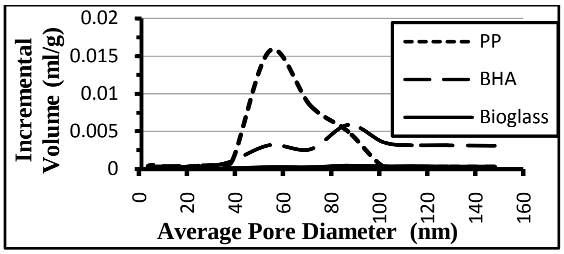

Figure 2 Incremental pore volume versus average pore diameter for the three samples.

The thermal properties of the BHA and the Bioglass were studied using Differential Scanning Calorimeter. It was found that these materials show a good thermal stability, and the absence of any peaks indicated the inertness of these materials up to 1200 ^{0}C.

Composite Preparation and Testing

Six different mixtures were prepared as shown in Table 2. Three of them were mixtures of PP and BHA and the other three were mixtures of PP and the Bioglass.

Table 2 Percentage composition of the six composites.

	1	2	3	4	5	6
PP	40	60	80	40	60	80
BHA	60	40	20	-	-	-
Bioglass	-	-	-	60	40	20

The samples were prepared by thorough mixing of the different components, and then the mixture was placed in a mould and pressed at 21 MPa at a temperature of 360 ^{0}C for three hours. At the end of the process, the composites were allowed to cool gradually. Pore size is an important factor in the compressive strength as it is established that the relationship between the strength and porosity of HA is inversely proportional in the log-linear scale [1].It is also established that the pore size is unaffected at this temperature [4]. The sample dimensions are 25 mm in diameter by 7 mm height. Figure 3 and Figure **4** show the resultant compressive strength and compression stiffness of the tested specimens respectively. The compressive strength increases with the increase of the amount of the PP in the sample. Moreover, the strength of the composite with the BHA is slightly higher than the composite with the Bioglass. This might be due to a higher surface bonding and compatibility between the PP and the BHA than between the PP and the Bioglass composed of silica.

However, for the case of the composite between the PP and the BHA, the composite with 60% PP and 40% BHA showed the highest stiffness. Moreover, the composites with the BHA have shown higher stiffness values than with the Bioglass. Again, this might be due to the higher bonding and compatibility between the PP and the BHA.

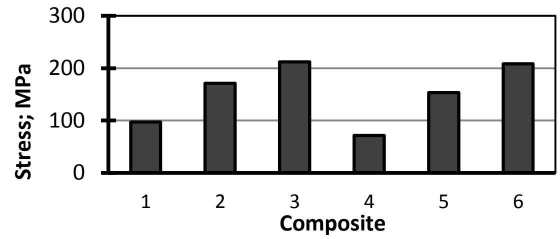

Figure 3 Compressive strength of the different composite samples

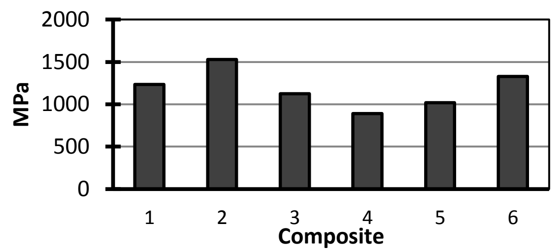

Figure 4 Compression stiffness of the different composite samples.

References

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