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## CONTENTS

<table>
<thead>
<tr>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>THE EFFECT OF HOLDING TIME ON THE MECHANICAL AND PHYSICAL PROPERTIES OF TITANIA-WOLLASTONITE-HYDROXYAPATITE COMPOSITES</td>
<td>4</td>
</tr>
<tr>
<td>OBJECTIVE &amp; METHODOLOGY</td>
<td>5</td>
</tr>
<tr>
<td>FINDINGS, CONCLUSION &amp; MAIN REFERENCES</td>
<td>6</td>
</tr>
</tbody>
</table>
THE EFFECT OF HOLDING TIME ON THE MECHANICAL AND PHYSICAL PROPERTIES OF TITANIA-WOLLASTONITE-HYDROXYAPATITE COMPOSITES

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ABSTRACT: The effect holding time and various amounts of additives on the TiO₂-HA-CaSiO₃ composites was investigated this study. TiO₂/CaSiO₃/HA composites were prepared and characterized by means of physical and mechanical properties. The addition of TiO₂ and HA to wollastonite was studied by means of bulk density and Vickers Hardness. The wollastonite composites containing TiO₂ (10-30 wt%) and HA (20-40 wt%) were sintered between 1230-1270°C, with a ramp rate of 10°C/min and a holding time of 1, 1.5 and 2 hours. The results indicate that a higher sintering temperature and a holding time of played a significant part in enhancing the physical and mechanical properties as compared to results shown by pure wollastonite, especially for composites containing higher TiO₂ (25-30wt%) and lower HA (20-25wt%).

Keywords: Wollastonite, Mechanical and Physical Properties, Sintering Parameters, Holding time

INTRODUCTION

The regeneration of long load-bearing bones like femur tibia, brings about a major concern in orthopedics because biomaterials and scaffolds that are unable to take part to the biological processes. These biological processes are responsible of bone formation and remodeling. It is known that, bone is a dynamic connective tissue that supports the system with structural framework and flexibility to the body [Copp et.al.]. In order to regenerate the bone, different types of biological events by the signaling molecules, growth factors and cells migration onto the site of injury are needed [Freyman et.al.].
OBJECTIVES

The aim of the present work was to investigate the influence of holding time on the physical and mechanical properties of TiO$_2$-CaSiO$_3$-HA composites.

LITERATURE REVIEW

As there are many accidents and wounding that happens to the skeletal system due to trauma, fracture and natural defects, there are many patients who are in need of aid for an internal fixation device or artificial joints to curb the bone problems. In these recent days, wollastonite has been studied as a good implant material as it is bioactive, non-toxic and compatible with hard tissues. The apatite layer that is formed is dense and uniform on flat and curved surfaces [Hata et.al.]. Ding and Liu have prepared Titania/wollastonite composites to improve pigments as they studied the bioactivity and compatibility properties of non-heat-treated titania-wollastonite composites. Based on the research, the phases produced were rutile and anatase, besides wollastonite in a lamellar structure [Zhao et.al.]. The samples with higher content of wollastonite formed an apatite layer on the substrate, after being immersed in SBF and these samples demonstrated osteoblast proliferation resulting in cytocompatible materials [Liu et.al.]. Generally, higher elastic modulus and higher chemical durability than silicates and phosphates are shown on ceramic compounds based on titania.

METHODOLOGY

The TiO$_2$ / HA doped Wollastonite (CaSiO$_3$), with different TiO$_2$ /HA were synthesized through co-precipitation method. Various weight percentages of TiO$_2$ and HA were mixed with CaSiO$_3$ by wet milling in ethanol in an ultrasonic machine. Subsequently, the mixture was milled for 1 hour, after which the slurry was dried at 60°C in an oven for 12 hours. The dried mixed was then sieved through a 212μm mesh stainless steel sieve to obtain a ready-to-press TiO$_2$ / HA powder. The mixed powder was pressed in a hardened steel circular (20 mm in diameter) and rectangular (80 x 50 x 8mm) mold and die set under a hydraulic pressure of 500 MPa.

Pressing was followed by the consolidation of the samples by ambient pressure sintering performed in air using a heating furnace (ModuTemp) at various temperatures ranging from 1230°C to 1270°C. The sintering profile set to sinter for all samples were a ramp-rate of 10°C/min for both heating and cooling, and holding time of 1, 1.5 and 2 hours prior to cooling to room temperature. All samples were polished using SiC papers (120, 240, 600, 800) from coarse to rough, followed by polishing with a diamond paste to 6μm, so as to obtain an optical reflective surface.

The samples were immersed in distilled water to measure density using the Archimedes’ method using a Mettler Toledo Balance AG204 densi-meter. The Vickers hardness was tested on the polished samples by means of the Vickers indentation method. The indentation load applied to the samples was kept constant at 98.1 N with a loading time of 10s. The compressive strength was determined using rectangular bar samples in order to determine compression at maximum load.
FINDINGS

The best holding time found to enhance the physical and mechanical properties of the TiO$_2$-CaSiO$_3$-HA composites was found to be a 1.5 hours with a ramp rate of 10°C. The best sintering temperature range was seen to be at low sintering temperatures (1230-1250°C), with 1240°C being the optimum temperature. The mechanical properties results obtained showed that the bulk density was slightly enhanced to 3.15 g/cm$^3$, approximately 9% higher than the theoretical density value (2.90 g/cm$^3$). Also, the Vickers hardness also showed increase to about 4.4GPa, slightly higher than the theoretical value of 4.1GPa.

CONCLUSION

The present study investigated the effect of holding times on the TiO$_2$ and HA additions to improve the physical and mechanical properties of wollastonite. The results show that 2 hours holding time the properties significantly enhanced the mechanical properties of wollastonite. The highest value of density obtained was about 3.15 g/cm$^3$, approximately 8.6% higher than the theoretical density value (2.90 g/cm$^3$). The mechanical properties of wollastonite also showed an increase above. Sintering at low temperatures (1230-1240ºC) with a holding time of 2 hours was seen to be the optimum temperature and holding time to achieve the best properties. Sintering above 1250ºC was found to cause detrimental changes to both physical and mechanical properties.

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