Thermal and In-vitro Study of Borate Based Bioglass

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Keywords: Bioglass, Boron, Mineralization, Osteo-conductive

Abstract

Bio-glasses have drawn attention of engineers and scientists in the field of bone tissue engineering due to its versatile properties than other Bioceramics such as ability to form bond with soft and hard tissues. Therefore, bio-glasses are considered as one of the promising materials for preparing three-dimensional porous scaffold, which can mimic the natural bone structure. In this regard, the bioglass 45S5 (discovered by Larry Hench 1960) was subject for intense research for decades and research is still continuing even after successful commercialization. But there is always search for new bioglass composition to overcome some hurdles like superior mechanical properties, controlled degradation rate and to find new functionality in the field of biomedical research. Borate based bioglass are comparative new class of bioglass in this regard. In some resent work it has been reported that borate based bioglass can show better bioactivity than silicate based glass. But not much has been reported with respect to mechanical properties, thermal behavior as well as bioactivity of borate based bioglass. In the present work three different 20B\textsubscript{2}O\textsubscript{3}-80(CaO- P\textsubscript{2}O\textsubscript{5}) (in weight percentage) frit glasses has been prepared by traditional melt quenching method. In these compositions Ca: P ratio was varied (1.65, 1.67 and 1.69) to investigate the effect of Ca: P ratio on thermal and in vitro biological properties of these glass. As these glasses are prone to crystallization at high temperature, therefore, crystallization behavior of all glasses has been investigated through DSC analysis. For scaffold preparation, the frit glasses need to be sintered at high temperature. Dilatometric studies have also been carried out to examine the sintering behavior. Porous Scaffolds have been prepared using naphthalene as pore former which is followed by sintering. The porosity and pore morphology has been studied using Mercury Porosimetry. Mechanical properties of porous as well as no porous glasses have also been measured through 3-point bending method and Brazilian Disc Test Method. The mineralization behavior of glass frit as well as glass scaffold has been tested by immersing the samples in SBF solution and examining them after 1, 3, 7, 14, 21 and 28 days. Mineralization behavior has been examined through XRD analysis and microstructure of deposited HCA layer has been examined through FESEM. Osteo-conductive property of the samples was tested using human osteoblast cell line (MG-63) in vitro. Initial cell- bioglass interaction has been evaluated in terms of cell adhesion and cell spreading using (immunocytochemistry). Effect of the samples on cell viability and proliferation has been tested using MTT assay and cell cycle analysis. Influence of the biomaterial on the differentiation of the bone cells were further tested by checking the expression of differentiation marker like Runx2. For the whole study commercial hydroxyapatite has taken as control. Study has revealed that the newly developed borate bioglasses are highly biocompatible and osteo-conductive in nature.
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1. Preparation and characterization of glass powders
2. Study of thermal Behavior
3. Study of sintering behavior and mechanical properties of bioactive glasses
4. Study of in vitro biocompatibility tests: Cell Proliferation, Cytotoxicity, Cell Cycle
5. Study of Bioactivity
Raw Material Used:
- $\text{H}_3\text{BO}_3$
- CaCO3
- $(\text{NH}_4)_2\text{HPO}_4$

Fig. 1  methodology of the glass powder preparation
Fig. 2 Powder X-ray diffraction pattern for glasses

Fig 3 DSC plot of the Batch-1 (S1) glass powder
Fig 4 DSC plot of the Batch-2 (S2) glass powder

Fig 5 DSC plot of the Batch-3 (S3) glass powder
Fig 6: Dilatometry plot of Batch-1 (S1), Batch-2 (S2) and Batch-3 (S3) bioglass sample
Flexural Strength, $\sigma = \left( \frac{3FL}{2bd^2} \right)$
Analysis of the Porous samples
Microstructure Analysis
Conclusions:
1. Borate glass sintering is governed by viscous flow sintering
2. Upon sintering $\beta$-Ca$_3$(PO$_4$)$_2$ emerges as major crystalline phase
3. High Density can be achieved through sintering hence high mechanical strength can be achieved
4. The glass and sintered glass products are not cytotoxic in nature and cell growth has also been observed
5. HA P formation is slow compared to other bioceramic such as 45S5 glass or TCP
6. HA P formation behavior is different than 45S5

Future Work
1. Understanding the dissolution behavior and control of dissolution behavior
2. Study of Relationship between pore structure and bioactivity
3. Study of In vitro and in vivo behavior
THANK YOU