CHAPTER-8

Conclusion and Future Scope

8.1 Summary:

This thesis focuses on synthesizing several bioactive glasses substituted with different transition metals, including three types of glasses:

1. Borosilicate glass was substituted with vanadium pentoxide.
2. 1393-B3 borate glass substituted with vanadium pentoxide.
3. 1393-B3 borate glass substituted with different compositions of titanium dioxide.
4. 1393-B3 borate glass substituted with different compositions of zirconium dioxide.
5. 45S5 glass was substituted with different compositions of zinc oxide after polarization.

The objective is to evaluate their suitability for bone tissue regeneration through in-vitro testing, mechanical characterization, electrical characterization, and biological characterization of transition metal substituted different glasses.

This text provides a concise overview of Chapters 1 to 8.

Chapters 1 and 2 provided a thorough introduction, literature review, and extensive explanation of the materials and procedures used.

Chapter 3 included the preparation and study of the vanadium pentoxide (0-2.5 wt%) substituted borosilicate bioactive glass system. Physical, chemical, mechanical and electrical properties have been studied. They were found to be increasing after V_2O_5 substitution. The *in-vitro* bioactivity property was studied using FTIR, XRD, and SEM-EDS techniques after they were immersed in SBF for different intervals of time. The results are studied considering the formation of a hydroxyapatite surface layer on the glass surface. Also, in-vitro and electrical properties are examined in relation to different V_2O_5 substituted borosilicate glass, which confirms the effect of the HA layer and electronic mechanisms due to the addition of vanadium. In-vitro hemocompatibility and cellular compatibility on MG-63 cell lines were carried out, and it was found that in hemocompatibility, these samples were compatible with human blood. Cellular compatibility is increased with increasing concentration of V_2O_5.

Chapter 4 presents the synthesis of 1393-B3 borate glass samples with the substitution of transition metals vanadium pentoxide with different concentrations (0-2.5 wt%). In-vitro bioactivity of the samples was studied with FTIR, XRD, and SEM-EDS techniques after they were immersed in SBF for different intervals of time. They were found tO increase after V_2O_5 substitution. Hemocompatibility studies show its compatibility with human blood. In-vitro cellular compatibility was studied on MG-63 human osteosarcoma cell line and found to be improved after V_2O_5 substitution.

Chapter 5 presents the fabrication of 1393-B3 borate glass samples with the inclusion of transition metal titanium dioxide in various compositions (0-2.5 wt%). Mechanical and thermal properties are determined and found to be improved after TiO_2 substitution. The in-vitro bioactivity of the samples was examined using FTIR, XRD, and SEM-EDS techniques after they were immersed in SBF for varying time intervals. All these properties found to be increased following TiO_2 substitution. Hemocompatibility investigations demonstrate its compatibility with human blood. In-vitro cellular compatibility was investigated on the MG-63 human osteosarcoma cell line and was shown to be improved following TiO_2 replacement.

Chapter 6 presents the synthesis of 1393-B3 borate glass samples in different compositions substituted with transition metal zirconium dioxide (0-2.5 wt%). Physical, mechanical and thermal properties are studied. And physical and mechanical properties enhanced by substituting ZrO_2. After immersing the materials in SBF various times, their in-vitro bioactivity was investigated using FTIR, XRD, and SEM-EDS techniques. It was also demonstrated that they were rising after ZrO_2 substitution. Studies on hemocompatibility show that it is compatible with human blood. Using the MG-63 human osteosarcoma cell line, in-vitro cellular compatibility was examined and demonstrated to improve with ZrO_2 substitution.

Chapter 7 presents the investigation of the bioactivity of transition metal zinc oxide (0-3 mole %) substituted 45S5 glass before and after polarization process. The ZBG bioglass samples were electro thermally poled by applying a voltage of 10 kV at 500ºC for 1 hour. FTIR investigated the effect of the substitution of ZnO for Na_2O on the in-vitro bioactivity after immersion in SBF. Further, the impact of electrical poling on the prepared ZBG samples was investigated by XRD, SEM-EDS, and AFM analysis. It was observed that the substitution of ZnO for Na_2O enhanced the dielectric properties of bioactive glasses. The electrical interaction between the polarized sample and ions present in SBF increased the development of HA layer leads to the calcium phosphate precipitation.

8.2 Future Scope of the present work:

- Use sol-gel process for processes to make bioactive glass and glass ceramics.
- Study of cellular biocompatibility of the bioactive glass samples after polarization of the samples.
- Anti-bacterial study of the samples.
- Investigation of ALP, and alizarin red stain activity of Bioactive glasses.
- Detail in-vivo animal study can be undertaken for assessing its suitability for possible future clinical operation.
- Preclinical trial needed for development for further clinical application.

Table 8.1 Comparative analysis of properties of all the synthesized materials.

Properties	**Borosilicate glass substituted with V_2O_5**	**1393-B3 glass substituted with V_2O_5**	**1393-B3 glass substituted with TiO_2**	**1393-B3 glass substituted with ZrO_2**	**45S5 glass substituted with ZnO**
Melting Temperature (°C)	1400°C	1100°C	1100°C	1100°C	1400°C
Density (gm/cc)	2.558-2.591	-----	2.31-2.48	2.43-2.71	2.7-2.76
pH value	7.4-8.05	7.4-8.51	7.4-8.86	7.4-9.38	2.7-2.76
Compressive Strength (MPa)	34.09-112.37	-----	98-125	71-87	-----
Flexural Strength (MPa)	-----	-----	33-54	38-69	-----
Thermal Properties	-----	-----	Studied	Studied	Studied
In-vitro analysis	HA layer formed	HA layer formed	HA layer formed	HA layer formed	HA layer formation increases after polarization
Electrical Properties	Increases after substitution	-----	-----	-----	Increases after polarization
Hemo-compatibility	Human blood compatible	Human blood compatible	Human blood compatible	Human blood compatible	-----
Cellular Compatibility with MG-63 cell line	Found maximum for 0.5% V_2O_5 substitution	Found maximum for 1% V_2O_5 substitution	Found maximum for 1% TiO_2 substitution	Found maximum for 2.5% ZrO_2 substitution	-----