PREFACE

Metallic implants are frequently utilized in load-bearing applications to repair or replace bone and other hard tissues that have been injured or shattered. The replacement of natural bone with an artificial one made of metallic material is not a novel concept in the field of medical science. Since the 1920s, medical professionals have found the stainless steel 316L to be an appropriate material to utilize as a mimic for bone and tissues. The development of Co-Cr alloys in the latter half of the 1960s led to the establishment of another option for SS 316L. Unfortunately, the long-term application presents a challenge due to the fact that these alloys give out hazardous oxides composed of Cr and Ni. Titanium and its alloy have gained much popularity in medical science due to its outstanding biocompatibility, strong resistance to wear and corrosion, and overall good mechanical strength.

The higher Young's modulus of metallic implant material causes stress shielding, resulting in earlier failure of the implant. Commercially pure titanium (CP-Ti) and Ti-6Al-4V possess lesser young' modulus than Co-Cr and SS 316 L alloys. Pure titanium possesses two crystal structures; at room temperature, it shows a closed-packed hexagonal (*HCP or α-phase*) structure, and at a temperature above 882 °C body-centered cubic (*BCC or β- phase*). These different phases of titanium control the different properties based on the crystal structure. Generally, the alpha phase shows strong resistance to corrosion, and the beta phase gives it suitable mechanical properties to use as an implant. Ti-6Al-4V is an excellent example of a combined α+β phase. Various elements, including Zr, Al, Cu, Nb, Mo, and Ta, are utilized depending on the application to stabilize the various phases of titanium. When alloyed with titanium, niobium demonstrates superior cytocompatibility to both surrounding cells and tissue. The metallic endosseous implant in long-life applications also failed by the growth of bacteria around the periphery of the implant. "Peri-implantitis" is the medical term for implant failure caused by bacteria. The continuous research is going on to develop an antibacterial metallic implant to resolve these problems with a metallic implant.

Many studies have been done on alloying copper to CP-Ti and Ti-6Al-4V to make it antibacterial and prevent the growth of S. aureus and E. coli. Bacteria around the periphery of the implant. The study shows that the inclusion of 5 wt.% copper is enough to make the titanium alloys antibacterial. Copper also enhances mechanical properties, corrosion, and wear resistance.

Thus, the present works aim to investigate phase formation, microstructure, mechanical behavior, corrosion confrontation, wear behavior, antibacterial ability, and biocompatibility of Nb inclusion to Ti-5Cu binary alloy. The novel Ti-5Cu-(0, 5, 10, and 15) %Nb alloys were successfully developed by the powder metallurgy technique. The different characterization techniques are used to investigate the various physical, chemical, mechanical, and biocompatibility properties of the sintered alloys.

The present thesis has been organized into eight chapters, as summarized below:

Chapter 1: This chapter comprises the introduction of titanium and its alloys as implant material with its specific properties and significant problem. Mechanical, corrosion, wear, antibacterial, and cytocompatibility properties are also discussed, followed by the application of the developed alloys in the present study.

Chapter 2: This chapter of the thesis presents the literature review of the topic related to the present study. The brief details of the history of biomaterials, metallic implants, advantages and disadvantages of metallic implants over ceramic and polymeric implants, the crystal structure of titanium, the effect of alloying different elements on the behavior of titanium alloy, peri-implantitis are reviewed in this chapter. Furthermore, the detailed literature survey of the mechanical behavior, corrosion, wear behavior, cytocompatibility, and antibacterial study of recently developed titanium alloys are discussed. Based on the literature survey, the motivation of the present study, along with the objective of the study, is given in this chapter.

Chapter 3: This chapter of the thesis contains the details of materials and experimental techniques involved in the development of the novel Ti-5Cu-(0, 5, 10, and 15) %Nb alloys. In the present study, five number of samples of each composition of size ϕ 15 mm × 5 mm were sintered using a conventional muffle furnace. The green samples of each composition were placed inside the hollow quartz tube of internal diameter 18 mm and sealed using gas flame with maintaining a high vacuum of 10^-6 torr using a diffusion pump. After sealing, the tube was kept inside the muffle furnace at 900 °C for 1 h with a heating rate of 4 °C/min. After the sintering, the phase analysis of the alloys is done using X-Ray Diffraction (XRD). Also, the microstructure, elemental analysis, and mapping of the element distribution of the alloys are done using High- resolution scanning electron microscopy (HR-SEM) equipped with EDAX. The detailed procedure, methodology, and effect of varying alloying elements on mechanical and corrosion behavior are discussed in this chapter. The analysis of corroded surfaces by SEM and X-ray photoelectron spectroscopy (XPS) techniques is also performed in this chapter. Followed by the reciprocating wear test of the alloys against the zirconia counterpart at 10 N, 15 N, and 20 N in simulated body fluid is thoroughly discussed in this section. The details procedure of cytocompatibility testing of the alloys in MTT MG-63 animal cells and the antibacterial property assessment of the alloys are also discussed in detail in this chapter.

Chapter 4: This chapter deals with the results obtained after phase analysis of both milled powder and sintered alloys, along with the microstructural analysis of the sintered alloys. The volume phase fraction of alpha and beta-titanium, crystalline size, and average lattice strain of different phases are also discussed in detail. The results of elemental analysis and mapping of the element formed after sintering are also discussed in this chapter. Furthermore, the result and discussion about density, microhardness, and compressive strength of the alloys are discussed in detail.

Chapter 5: The potentiodynamic polarisation approach was used to investigate the corrosion behavior of the alloys in order to guarantee the stability of the alloys in their respective chemical environments. In this chapter, an in-depth discussion is done on the findings that were obtained from the open-circuit potential (OCP), electrochemical impedance spectroscopy (EIS), and potentiodynamic polarisation tests performed on the alloys in SBF. This chapter presents the findings and a discussion of the SEM and XPS analyses of the compound that formed on the surface of the alloys as a result of the corrosion test. The results of the reciprocating wear and friction test performed on the alloys in SBF are also discussed in this chapter. The results of friction coefficient, wear volume, depth, and width of the worn track, as well as wear rate obtained at different loadings of the alloys against the zirconia ball, are described in detail. These findings were acquired by rubbing the zirconia ball against the alloys. SEM, EDAX, and SPM are used to conduct the analysis of worn surfaces after the wear test. The results of these analyses are also described in detail in this chapter.

Chapter 6: This chapter contains the result and discussion about the cell culture, proliferation, viability, and antibacterial test of the alloys. The cell culture test is carried out in MG-63 animal cells for 3 days, 5 days, and 7 days to see the growth of cells on the surface of the alloys. The counts of the cell as also reported in this chapter. Also, the results and discussion about the antibacterial test of the alloys carried out in *Staphylococcus aureus (S. aureus)* and *Escherichia coli (E. coli)* bacteria are discussed in this chapter.

Chapter 7: This chapter contains the significant conclusions of all the tests conducted on the alloys in the present study. The findings in this chapter demonstrate that the currently developed alloys can perform their intended role, which is to simulate the natural load-bearing bone and hard tissues found in the human anatomy. The future scope of the above study is also contained in this chapter.