ABSTRACT

People currently suffering from accidents or various joint diseases, such as arthritis, osteoporosis, and dental issues, may require surgery. Damaged body parts can be replaced with artificial implants made from polymers, metals, or ceramics. However, certain inadequacies persist with these materials: metals and alloys can release toxic metal ions and pose aesthetic issues, while organic polymers often suffer from poor wear resistance. Therefore, further research on nonmetallic implant materials is crucial for advancing implant technology.

Nowadays, ceramic materials are commonly used as implants due to their excellent wear resistance, biocompatibility, and aesthetic qualities. Among these, stabilized zirconia (ZrO_2), alumina (Al_2O_3), and their composites are particularly notable for their exceptional mechanical and biological properties. However, these ceramics are biologically inert. This shortcoming can be addressed by modifying them to become bioactive instead of bio-inert. Generally, incorporating bioactive ingredients is a significant alternative to impart bioactivity and also enhances the cellular viability and antibacterial response to these ceramics.

This thesis comprehensively examines the synthesis and evaluation of bioceramic composites, consisting of stabilized zirconia and alumina ceramics (3Y-TZP, 8Mg-PSZ, and ZTA) combined with 13-93 bioactive glass (BG) particles as reinforcing fillers. The matrix materials are synthesized using the combustion route, while the filler materials are prepared via the sol-gel method. All composites are sintered at a low temperature of 1250°C. The study systematically evaluates the effects of varying filler content (in wt.%) on the structural, mechanical, in vitro bioactivity and degradation, cellular response, and antibacterial properties of the composites.

Bioceramic composite materials, having general weight composition [(100-x) (3Y-TZP) – x (13-93 BG)] where x = 0 to 25 wt%, has been prepared. The relative density and

mechanical properties, such as flexural and compressive strength, are found to increase up to 10 wt% of BG content; afterward, it decreases. The hardness is increased with BG addition in 3Y-TZP ceramics. The *in-vitro* degradation indicates the dissolution and apatite layer formation after immersion in a simulated body fluid (SBF) solution. The cell proliferation ability of the composite is increased with increasing the BG concentration. The antibacterial result demonstrates that the presence of BG considerably reduces the bacterial cells' viability on the composite samples.

The bioceramic composites, having the general formula [(100-x) (8Mg-PSZ) – x (13-93 BG)] where x = 0 to 25 wt%, have been prepared. Elastic modulus decreases with the addition of BG content up to 15 wt%; after that, it slightly increases up to 25 wt%. The *in-vitro* bioactivity and bio-degradation are increased by enhancing the BG contents up to 25 wt%. The biocompatibility increases with BG concentration (up to 25 wt%). The antibacterial result demonstrates that the presence of BG considerably reduces the bacterial cells' viability on the composite samples.

The bioceramic composites, having the general formula [ZTA–xBG (x = 0, 5, 10, 15, and 25 wt%)] composites have been synthesized. Mechanical properties such as flexural strength and hardness are enhanced by BG content up to 25 wt%. *In-vitro* analysis reveals that both degradation and bioactivity increase as BG concentrations increase. Adding BG to ZTA improves cellular viability with BG content up to 25 wt%. The antibacterial result shows that the viability of the bacterial cells on the composites has significantly decreased with BG content.

Based on density, mechanical properties, and biological properties results, these three composites (3Y-TZP/BG, ZTA/BG, and 8Mg-PSZ/BG) are compared and found that the 3Y-TZP/BG composites have the best result. Further, machinability and tribological studies are performed on 3Y-TZP/BG composite samples only.

The machinability of 3Y-TZP/BG composites is performed on the abrasive air jet machine (AAJM), and machinability is evaluated in terms of MRR (material removal rate) and SR (surface roughness) and material removal mechanics (MRM). The machinability is studied as a function of BG composition (0 to 25 wt%) and machining temperature (room temperature - 600°C). It is found that MRR decreases with the increase in the concentration of bioactive glass (BG) while it increases with the increase in the machining temperature. The SR is found in the opposite trend. Analysis of machined surface indicates that mainly ploughing with plastic deformation and large erosion craters are the predominant mechanisms at an elevated temperature, while at room temperature, brittle fracture, grain ejection, micro-crack propagation, and exfoliation are responsible for material removal.

Further, the effect of bioactive glass (BG) addition on the tribological behavior of 3Y-TZP/BG composites is evaluated. Tribological results indicate that the wear rate and coefficient of friction (COF) first decrease up to 10 wt% of BG and then increase up to 25 wt% of BG content. 3Y-TZP with 10 wt% of BG displays superior antifriction and wear resistance properties, with an average COF of 0.17 and a wear rate of 0.63×10^{-6} mm^3 per mm of sliding distance. Line and surface roughness are almost enhanced by enhancing the BG content into 3Y-TZP ceramic. Maximum pull-out is observed on the surface of the pure 3Y-TZP sample, and minimum pull-out is witnessed on the surface of the sample containing 10 wt% of BG content.

Key Words: *Bioglass; Ceramics; Bioceramic composites; Biodegradability; Cellular viability; Antibacterial response; Machinability; Material removal rate; Wear*