

## Table of Contents

<b>Chapter 1: Introduction</b>	<b>1-26</b>
1 Introduction	2
1.1 Background	2
1.2 Biomaterials	4
1.2.1 Applications of biomaterials	5
1.2.2 Desirable properties of biomaterials	6
1.3 Bioceramics and its types	8
1.3.1 Zirconia based bioceramic material	9
1.3.2 Alumina-based bioceramic material	11
1.3.3 Zirconia and alumina-based bioceramic materials as the matrix	12
1.3.3.1 3Y-TZP bioceramic	12
1.3.3.2 8Mg-PSZ bioceramic	13
1.3.3.3 ZTA bioceramic	14
1.3.4 Bioactive glasses as the reinforcement	14
1.3.5 Biocomposite materials	15
1.3.5.1 Types of biocomposite materials	17
1.3.5.2 Properties and applications of biocomposite materials	18
1.3.5.3 Machinability/mechanical properties of biocomposite	18
1.3.5.4 Tribological behavior of biocomposite materials	21
1.3.5.5 Biological properties of biocomposite materials	22
1.3.5.5.1 <i>In-vitro</i> bioactivity	22
1.3.5.5.2 <i>In-vitro</i> biodegradability	22
1.3.5.5.3 <i>In-vitro</i> cellular response	23
1.3.5.5.4 Antibacterial response	23
1.4 Theme of the work	24
1.5 Organization of the thesis	24
<b>Chapter 2: Literature Review</b>	<b>27-56</b>
2.1 Introduction	28
2.2 Synthesis of matrix ceramics (3Y-TZP, 8Mg-PSZ, and ZTA)	29
2.3 Synthesis of reinforcement material (bioactive glass)	30
2.4 Stimulating bone growth	31
2.5 Enhancement of <i>in-vitro</i> bioactivity	33
2.6 Cell adhesion	34
2.7 Bacterial adhesion	37
2.8 Addition of different bioactive glass into various zirconia-based bioceramic composites	39
2.8.1 Ytria-stabilized tetragonal zirconia polycrystals (Y-TZP)	39
2.8.2 8-mol% Magnesia-partially stabilized zirconia (Mg-PSZ)	44
2.8.3 Zirconia-toughened alumina (ZTA)	45
2.9 Machinability study of zirconia-based bioceramics composites	47

2.10 Tribological study of zirconia-based bioceramic composites	50
2.11 Summary of literature review	54
2.12 Research objectives	55
<b>Chapter 3: Materials, Methodology and Characterization Techniques</b>	<b>57-86</b>
3.1 Overview	58
3.2 Materials and methods	58
3.2.1 Synthesis of 3-mol% yttrium stabilized zirconia (3Y-TZP)	58
3.2.2 Synthesis of 8-mol% magnesia stabilized zirconia (8Mg-PSZ)	59
3.2.3 Synthesis of 30-mol% zirconia toughened alumina (ZTA)	61
3.2.4 Synthesis of 13-93 bioactive glass (BG)	62
3.2.5 Synthesis of 3Y-TZP/13-93 BG biocomposites	63
3.2.6 Synthesis of 8Mg-PSZ/13-93 BG biocomposites	64
3.2.7 Synthesis of ZTA/13-93 BG biocomposites	65
3.2.8 Granulation and pellet processing	65
3.2.9 Sintering	65
3.3 Materials characterization techniques	66
3.3.1 Particle size analysis	66
3.3.2 X-ray diffraction analysis	67
3.3.3 Fourier transform infrared spectroscopy (FTIR)	71
3.3.4 Field emission scanning electron microscope (FESEM) with EDS analyser	73
3.3.5 Density and porosity measurements	74
3.3.5.1 Bulk density	74
3.3.5.2 Relative density & percentage porosities	75
3.3.6 Mechanical properties measurements	75
3.3.6.1 Flexural strength	75
3.3.6.2 Compressive strength	76
3.3.6.3 Hardness	76
3.3.6.4 Elastic moduli	77
3.3.7 Assessment of pH, <i>in-vitro</i> bioactivity, and biodegradation measurement	77
3.3.7.1 pH, and <i>in-vitro</i> bioactivity analysis	77
3.3.7.2 Assessment of <i>in-vitro</i> biodegradation test	79
3.3.8 <i>In-vitro</i> cellular response	79
3.3.8.1 MTT assay	80
3.3.8.2 Fluorescence microscope analyses	80
3.3.8.3 Antibacterial analysis	80
3.3.8.4 Live/ Dead ratio	81
3.3.9 Abrasive air jet machining (AAJM)	81
3.3.10 Tribological study	84

**Chapter 4: Impact of 13-93 bioactive glass addition on the structural, mechanical, in-vitro degradation, cell culture, and antibacterial response of the 3Y-TZP-based biocomposite materials** **87-111**

4.1 Introduction	88
4.2 Results and discussion	89
4.2.1 Particle size, XRD, SEM, and FTIR analysis of the prepared precursors	89
4.2.2 XRD and microstructural analysis of the sintered composites	92
4.2.3 Density and mechanical properties of sintered composites	97
4.2.4 Biodegradation and bioactivity study	99
4.2.4.1 pH analysis	99
4.2.4.2 Biodegradation analysis	101
4.2.4.3 Bioactivity analysis	102
4.2.4.4 Cell culture study	105
4.2.4.4.1 MTT assay	105
4.2.4.4.2 Fluorescence microscopy study	107
4.2.4.5 Antibacterial response	108
4.3 Summary	111

**Chapter 5: Impact of 13-93 bioactive glass addition on the structural, mechanical, in-vitro degradation, cell culture, and antibacterial response of the Mg-PSZ-based biocomposite materials** **112-136**

5.1 Introduction	113
5.2 Results and discussion	114
5.2.1 Particle size, XRD, SEM, and FTIR analysis of the prepared precursor	114
5.2.2 XRD and microstructural analysis of the sintered composites	116
5.2.3 Measurement of density and mechanical properties	121
5.2.4 Biodegradation and bioactivity study	125
5.2.4.1 pH analysis	125
5.2.4.2 Biodegradation analysis	125
5.2.4.3 Bioactivity analysis	127
5.2.4.4 Cell Culture Study	130
5.2.4.4.1 MTT assay result	130
5.2.4.4.2 Fluorescence microscopy study	133
5.2.5 Antibacterial analysis	134
5.3 Summary	136

**Chapter 6: Impact of 13-93 bioactive glass addition on the structural, mechanical, in-vitro degradation, cell culture, and antibacterial response of the ZTA-based biocomposite materials** **137-158**

6.1 Introduction	138
------------------	-----

6.2 Results and discussion	139
6.2.1 Particle size, XRD, SEM, and FTIR analysis of the prepared precursor	139
6.2.2 XRD and microstructural analysis of the sintered composites	142
6.2.3 Density and mechanical properties of sintered composites	145
6.2.4 Biodegradation and bioactivity study	146
6.2.4.1 pH study	146
6.2.4.2 Biodegradation analysis	148
6.2.4.3 Bioactivity analysis	148
6.2.5 Cell culture study	151
6.2.4.4.1 MTT assay	151
6.2.4.4.2 Fluorescence microscopy study	153
6.2.4.5 Antibacterial analysis	155
6.3 Summary	157

**Chapter 7: Impact of 13-93 bioactive glass addition on the machinability behavior of 3Y-TZP-based biocomposite materials** **159-180**

7.1 Introduction	160
7.2 Results and discussion	162
7.2.1 Abrasive air jet machining at room and elevated temperature	162
7.2.1.1 Abrasive materials and surface morphology before machining	162
7.2.1.2 Effect of BG additions on the MRR	163
7.2.1.3 Effect of machining temperature on the MRR	165
7.2.1.4 Machined surface morphology at room temperature	166
7.2.1.5 Machined surface morphology at elevated temperature	168
7.2.1.6 The machined surface topographies	170
7.2.1.7 Material removal mechanics	174
7.3 Summary	177

**Chapter 8: Impact of 13-93 bioactive glass addition on the tribological behavior of 3Y-TZP-based biocomposite materials** **181-197**

8.1 Introduction	182
8.2 Results and discussion	183
8.2.1 Coefficient of friction (COF) study	183
8.2.2 Width, depth, and area of wear scar	185
8.2.3 Wear volume and wear rate	187
8.2.4 Worn surface characterization	188
8.2.5 Surface profilometry analysis	192
8.3 Summary	195

<b>Chapter 9: Conclusions and future perspective</b>	<b>198-204</b>
9.1 Conclusions	199
9.2 Future perspective	203
<b>References</b>	<b>205-245</b>
<b>List of Publications</b>	<b>246</b>
<b>Attended International Conferences</b>	<b>248</b>