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Numerical Optimisation of Biomedical Implant Characteristics for Increased Service Life

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ABSTRACT

The research presented in this thesis focuses on the development of a numerical optimisation technique with the aim to decrease implant stress shielding which in turn could increase Total Hip Arthroplasty (THA) service life and reduce patient discomfort by employing a distributed stiffness along implant length.

THA is a frequently performed operation, in which the natural hip joint is replaced with a mechanical joint that requires implantation of a 'stem' within the femoral shaft. While THA is generally regarded as a successful method of restoring limb function, it is possible to improve current implant design and consequently increase service life to accommodate increasing human life expectancy and the decreasing age of THA recipients.

Initially, various numerical models of intact femora are constructed and studied in order to obtain an appreciation of the parameters (such as loading and boundary conditions) that influence solution accuracy. The results of which are the generation of accurate and efficient intact femoral numerical models, based on extracted cadaveric specimens.

Commercially available THA stems are assessed for their stress shielding (reduction in stress level post implantation) characteristics using the parameters specified within the previously constructed intact numerical models. The implanted femoral model containing the THA stem that demonstrated the most favourable stress shielding characteristics was used as a platform for numerical optimisation techniques.

Numerical optimisation techniques were applied to the implanted femoral model to generate homogeneous and distributed THA stem stiffness values that minimised stress shielding without exceeding maximum allowable stresses within the cement, which acts to locate and restrain the implanted THA stem.

The research presented here has found that through distributing stiffness along THA stem length, significant reductions in stress shielding can be achieved without exceeding maximum allowable stresses within the cement, possibly extending service life in comparison to homogeneous THA stems.

CONTENTS

ABSTRACT	i
CONTENTS	iii
LIST OF FIGURES AND TABLES	ix
STATEMENT OF ORIGINALITY	xv
ACKNOWLEDGEMENTS	xvi
Chapter 1	
INTRODUCTION	1
1.1 Total Hip Arthroplasty (THA)	1
1.1.1 Problems Associated with THA	2
1.2 THA Medical Procedure	4
1.3 Significance and Motivation	6
Chapter 2	
LITERATURE REVIEW	9
2.1 THA Femoral Implant Characteristics	9
2.1.1 Cemented THA Stem Implantation	10
2.1.2 Cementless THA Stem Implantation	12
2.1.3 THA Stem Surface Finish and Implications in Cemented THA	13
2.1.4 Material Biocompatibility	17
2.1.5 Advances in THA Stem Design	18
2.2 Characteristics of Bone Material	20
2.2.1 Compact Bone Material Characteristics	21

2.2.2	Cancellous Bone Characteristics	23
2.2.2.1	Structure	23
2.2.2.2	Mechanical Properties	24
2.3	Numerical Models	29
2.3.1	Simplified Numerical Modelling Techniques	30
2.3.2	Modelling Femoral Bone Geometry	31
2.3.2.1	Generic Femoral Models	31
2.3.2.2	Subject-Specific Numerical Femoral Models	33
2.3.3	Numerically Modelling Bone Structure and Geometry	34
2.3.3.1	Numerically Modelling Compact Bone	34
2.3.3.2	Numerically Modelling Cancellous Bone	35
2.3.4	Numerically Modelling Material Interfaces	36
2.3.5	Numerically Modelling Femoral Loading	38
2.3.5.1	Femoral Loading Cycle	39
2.3.5.2	Modelling Muscle Inclusion	39
2.3.5.3	Femoral Loading Resulting from Muscular Wrapping	43
2.3.5.4	Femoral Joint Boundary Conditions	43
2.3.5.5	Muscular Loading Magnitude for Femoral Models	44
2.3.5.6	Modelling Muscular Load Attachment to the Femur	45
2.3.5.7	Changes in Femoral Loading Post Implantation	46
2.3.6	Choosing and Calculating Resultant Quantities	47
2.3.6.1	Mechanical Failure	47
2.3.6.2	Stress Shielding of Femoral Regions	47
2.3.6.3	Quantifying THA Stem Loosening	49
2.3.7	Femoral Model Mesh Characteristics	49
2.3.8	Solution Accuracy	50
2.3.9	Numerical Optimisation Techniques for THA Stem Analysis	50
2.3.9.1	Composite Materials and Optimisation	52
2.3.9.2	Numerical Modelling as a Tool for Optimisation	53
2.3.9.3	2-Dimensional Optimisation within Numerical Modelling	54
2.3.9.4	3-Dimensional Optimisation within Numerical Modelling	56
2.3.10	Modelling Adaptive Bone remodelling	58
2.4	Literature Review Summary	58

Chapter 3

PRELIMINARY NUMERICAL MODELLING OF THE INTACT FEMORAL SYSTEM 60

3.1 Introduction 60

3.2 Research Aim 60

3.3 Preliminary Intact Femoral Model Construction 61

3.3.1 Model Geometry Generation 61

3.3.2 Model Meshing 62

3.3.3 Material Characteristics 64

3.3.4 Model Loading 65

3.3.5 Model Solution 66

3.4 Model Validation 66

3.5 Conclusion 69

Chapter 4

UNDERSTANDING RESULTANT SENSITIVITY TO CHANGES IN MODEL CHARACTERISTICS 71

4.1 Introduction 71

4.2 Research Aim 72

4.3 Model Generation 72

4.3.1 Model Acquisition 73

4.3.2 Quantifying Resultant Trends 74

4.4 Choice of Loadstep 76

4.5 Refinement of Muscular Inclusion 79

4.6 Anatomically Accurate Distribution of Muscular Load 82

4.7 Knee Restraint Boundary Condition 83

4.8 Model Verification 87

4.9 Conclusion 89

Chapter 5

**GENERATION OF AN IMPLANTED FEMORAL MODEL USING
ADVANCED MODELLING TECHNIQUES 93**

5.1 Research Aim 93

5.2 Introduction 93

5.3 Methodology 96

 5.3.1 Cadaveric Specimen Selection 96

 5.3.2 Implant Selection 97

 5.3.3 Surgical Extraction of the Cadaveric Femora 98

 5.3.4 Numerical Model Generation for the Intact Femora 99

 5.3.4.1 CT Scanning 99

 5.3.4.2 Finite Element Model Generation 100

 5.3.4.3 Intact Femoral Model Boundary Conditions 104

 5.3.5 Numerical Models of Implanted Femora 104

 5.3.5.1 Creation of THA Stem Meshes 104

 5.3.5.2 Surgical Implantation of Cadaveric Femora 106

 5.3.5.3 CT Scanning of Implantation of Cadaveric femora 107

 5.3.5.4 Implanted Model Generation 108

 5.3.5.4.1 Stem ‘B’ Implanted Femoral Model 108

 5.3.5.4.2 Stem ‘A’ Implanted Femoral Model 109

 5.3.5.5 Implanted Femoral Model Boundary Conditions 111

5.4 Analysis 112

5.5 Model Results and Discussion 112

 5.5.1 Intact Femoral Models 113

 5.5.2 Implanted Femoral Models 115

5.6 Model Verification 118

5.7 Conclusion 119

Chapter 6

OPTIMISATION OF IMPLANT CHARACTERISTICS FOR EXTENDED SERVICE LIFE 120

6.1	Introduction	120
6.2	Research Aim	121
6.3	Investigation into Stress Shielding and Maximum Cement Stress Response to Variation of Homogeneous THA Stem Stiffness	121
6.3.1	Research Methodology	121
6.3.2	Results	122
6.3.3	Discussion	124
6.4	Investigation into the Optimisation of THA Stem Stiffness Distribution....	125
6.4.1	Research Methodology	126
6.4.2	Results	129
6.4.3	Discussion	132
6.4.4	Conclusion	137

Chapter 7

SUMMARY AND CONCLUSIONS 138

Chapter 8

FUTURE WORK 141

Glossary 143

References 146

Appendix A 154

Appendix B 167