COMPUTED TOMOGRAPHY TECHNIQUE FOR THE MEASUREMENT OF BONE DEFECTS ADJACENT TO UNCEMENTED ACETABULAR COMPONENTS OF TOTAL HIP REPLACEMENT

DEVELOPMENT, VALIDATION AND CLINICAL APPLICATION

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ABSTRACT

This thesis describes work, the aim of which was to develop a computed tomography (CT) technique that provides accurate and reliable volumetric measurement of bone defects adjacent to uncemented metal-backed acetabular components of total hip replacement (THR).

Periprosthetic osteolysis (PO) around THR is a major clinical problem in the mid-to long term post-operative period. Some implants remain well fixed in the presence of significant bone loss, and the hips may also be asymptomatic. However, undetected, the PO can lead to dramatic implant failure, or periprosthetic fracture, requiring complex and expensive revision surgery, with associated morbidity. Clinical assessment of THR for PO has relied on plain radiographs. However, numerous studies have shown that there are major limitations of this method in detecting the presence and extent of osteolysis and the volume of the defects cannot be quantified. Therefore, clinical management decisions regarding the need to revise prostheses for PO have been based on this unreliable diagnostic tool. Until recently, the use of CT to detect and measure defects was not effective because of the resulting artifact from the metallic components of the THR prostheses.

The studies described in this thesis represent the development, validation and the clinical application of a CT technique for quantification of acetabular periprosthetic osteolysis after THR.

In the first in-vitro validation study, a CT protocol was developed using a conventional CT scanner with limited CT scale (up to 4,000 Hounsfield units [HU]). The CT operating conditions were determined that enabled volumetric measurements that were accurate to within 96% for small and large defects and precise to greater than 98% for small and large defects. Since the ilium is the most commonly affected site by PO, and is an area almost free of metallic artifact, this technique is applicable for use with conventional CT scanners with limited CT scale.

In the second in-vitro validation study, a CT protocol was developed to use a multi-slice spiral CT scanner with an extended CT scale (up to 40,000 HU) for the measurement of acetabular periprosthetic bone defects. This technique enabled volumetric measurements of bone defects in all acetabular and periacetabular areas.

In the third study, the clinical application of the developed CT technique was investigated in two sub-studies.

The aim of the first clinical study was to determine, using quantitative CT, the distribution, volume and rate of progression of PO lesions around 46 cementless THR prostheses in 33 patients. The findings showed that, in the long term, there were differences in the distribution of osteolytic lesions between different designs of cementless acetabular components. In particular, osteolysis commonly involved sites of access of the joint fluid- the peripheral region of the components, where prosthesis fixation is important, and fixation screw holes.

The aim of the second clinical study was to use quantitative CT to determine the progression of osteolysis and the factors that may associate with it, including component migration, liner polyethylene wear, and patient variables, in 30 patients with 38 cementless acetabular components. The data provided the first reliable information on the progression of osteolytic lesions around uncemented THR prostheses and suggested that, for THR, the rate of polyethylene wear is a strong predictor of PO progression.

The results from in-vitro studies and the findings from the clinical studies suggest that the use of this CT technique allows investigation of the natural history of osteolytic lesions, and will enhance preoperative planning, improve monitoring of THR patients, and enable measurement of the outcomes of new ways to manage PO.

Declaration

NAME: ROUMEN BOTEV STAMENKOV PROGRAM: MASTERS BY RESEARCH

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Dedication

To my family for their endless love, understanding and support.

PUBLICATIONS ARISING

The work of this thesis has resulted in the publication of the following papers:

PUBLISHED PAPERS

1. **Stamenkov R,** Howie D, Taylor J, Findlay D, McGee M, Kourlis G, Carbone A, Burwell M. Measurement of bone defects adjacent to acetabular components of hip replacement. Clin Orthop Relat Res 412: 117-124, 2003.

2. Holding C, Findlay D, **Stamenkov R**, Neale S, Helen L, Dharmapatni A, Callary S, Shrestha K, Atkins G, Howie D, Haynes D. The correlation of RANK, RANKL and TNFα expression with bone loss volume and polyethylene wear debris around hip implants. Biomaterials 27 (30): 5212-5219, 2006.

3. Howie D, Neale S, **Stamenkov R**, McGee M, Taylor D, Findlay D. Progression of acetabular periprosthetic osteolytic lesions measured with computed tomography. J Bone Joint Surg 89-A: 1818-1825, 2007.

ARTICLES IN PRESS

1. **Stamenkov R,** Howie D, Neale S, McGee M, Taylor D, Findlay D. Distribution of periacetabular osteolytic lesions varies according to component design. J Arthroplasty, Article in Press, 2009.

ABBREVIATIONS

AP	Antero-Posterior
ARPANSA	Australian Radiology Protection and Nuclear Safety Agency
BMD	Bone Mineral Density
CoCr	Cobalt Chrome
CT	Computed Tomography
$CTDI_w$	Weighted Computed Tomography Dose Index
CV	Coefficient of Variation
DEXA	Dual Energy X-ray Absorptiometry
DICOM	Digital Imaging and Communication in Medicine
DLP	Dose-Length Product
EBRA	Ein Bild Roentgen Analyse
FOV	Field Of View
HHS	Harris Hip Score
HU	Hounsfield Unit
ICRP	International Commission on Radiological Protection
ICC	Intra-class Correlation Coefficient
JR	Joint Replacement
kV	Kilovolts
MMP-1	Matrix Metalloprotease
mAs	Milliamperes
mGy	Milligray
MRI	Magnetic Resonance Imaging
mSv	Millisieverts
OPG	Osteoprotegerin
PO	Periprosthetic Osteolysis

PE	Polyethylene
PMMA	Polymethylmethacrylate
ROI	Region of Interest
RSA	Radiostereophotogrametric Analysis
SD	Standard Deviation
THR	Total Hip Replacement
TKR	Total Knee Replacement
TNF	Tumour Necrosis Factor
TNFα	Tumor Necrosis Factor α

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