A Comparison of Wear of 36 mm and 28 mm Metal-on-
Highly Cross-Linked Polyethylene Articulations in Primary
Total Hip Replacements

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Contents

List of tables ...................................................................................................................... vi
List of figures ................................................................................................................... viii
Abstract .............................................................................................................................. x
Acknowledgements ......................................................................................................... xiii
Abbreviations and glossary ............................................................................................. xv
Chapter 1: Introduction .................................................................................................... 1
Chapter 2: Literature review ............................................................................................. 3
  2.1 Content of the literature review .................................................................................. 3
  2.2 Structure of the literature review ............................................................................... 3
  2.3 Research questions and limitations of the literature ............................................... 4
  2.4 Metal-on-polyethylene total hip replacements ........................................................... 6
    2.4.1 Total hip replacement surgery ........................................................................... 6
    2.4.2 Reasons for revision ......................................................................................... 8
    2.4.3 The role of large metal-on-HXLPE articulations ............................................. 8
  2.5 Conventional polyethylene to cross-linked polyethylene .......................................... 10
    2.5.1 The clinical importance of wear rates of polyethylene liners ......................... 10
    2.5.2 Defining clinically important wear rates ......................................................... 13
    2.5.3 The development and chemistry of cross-linked polyethylene ...................... 16
    2.5.4 Proposed advantages of cross-linked polyethylene ....................................... 18
    2.5.5 Limitations of the current literature on cross-linked polyethylene ............... 19
  2.6 Wear performance of total hip replacements ............................................................ 21
    2.6.1 Wear terminology and concepts ....................................................................... 21
    2.6.2 Clinical performance of first-generation cross-linked polyethylene ............. 26
    2.6.3 Bedding-in/creep and wear ............................................................................. 27
    2.6.4 Comparative studies of large and standard articulations ............................... 29
      2.6.4.1 Bedding-in/creep ....................................................................................... 29
    2.6.5 Studies examining wear rates of younger patients ......................................... 35
    2.6.6 Comparative prevalence of osteolysis in short- to medium-term ................. 35
  2.7 Polyethylene wear ..................................................................................................... 37
    2.7.1 Wear of polyethylene acetabular liners ......................................................... 37
    2.7.2 Polyethylene wear particle generation and periprosthetic particle migration ................................................................................................................................. 39
  2.8 Radiographic methods of polyethylene-wear measurement .................................... 41
2.8.1 A brief history of techniques and their utility ...........................................41
2.8.2 PolyWare™ ................................................................................................46
2.8.3 Volumetric wear measurement .................................................................48
2.8.4 Two-dimensional versus three-dimensional wear measurement techniques ...........................................50
2.9 Wear interpretation and wear study design ..................................................52
  2.9.1 Creep and bedding-in ..............................................................................52
  2.9.2 Negative wear ..........................................................................................53
  2.9.3 Imaging technique and quality .................................................................55
  2.9.4 Clinical context of the utility of wear measurement techniques ..........57
  2.9.5 Reporting of wear outcomes and summary of limitations .................58
2.10 Summary of the literature review ...............................................................61
2.11 Aims and hypotheses ..................................................................................62
  2.11.1 Aims ........................................................................................................63
  2.11.2 Hypotheses ............................................................................................63

Chapter 3: Methodology .....................................................................................65
  3.1 Study conduct and data collection ..............................................................65
    3.1.1 Sample population and randomised controlled trial methodology .......65
    3.1.2 Clinical and radiographic follow-up .......................................................67
    3.1.3 Data collection and image processing .................................................69
  3.2 Data analysis ................................................................................................69
    3.2.1 PolyWare™ analysis .............................................................................69
    3.2.2 Wear analysis .........................................................................................74
  3.3 Inter- and intra-observer error ....................................................................81

Chapter 4: Results ...............................................................................................83
  4.1 Cohort demographics and component positioning ......................................83
  4.2 Intra-observer and inter-observer reliability .............................................87
  4.3 Two-dimensional femoral head penetration across points .........................88
  4.4 Total volumetric wear across time points ..................................................90
  4.5 Bedding-in/creep ........................................................................................91
  4.6 Annual wear rates .......................................................................................91
    4.6.1 Annual two-dimensional wear rates .....................................................91
    4.6.2 Annual volumetric wear rates .............................................................94
  4.7 Statistical modelling of the data (mixed linear effects model) ....................99
  4.8 Proportion of cohorts with elevated 2DWRs and VWRs ..........................100
4.9 Demographic and component characteristics of patients with elevated 2DWRs and VWRs...

Chapter 5: Discussion ................................................................. 105

5.1 Synthesis of results to literature and their interpretation ................. 105
5.2 Limitations of the study and measurement technique .................... 110
5.3 Significance and future directions ........................................... 113
5.4 Conclusions and implications for further research ......................... 117

Appendix A: Published RCT Methodology ..................................... 118
Appendix B: Evidence of Trial Ethics Approval and Registration ............. 119
Appendix C: RCT Stratification ..................................................... 120
Appendix D: Statistical Modelling Tables ....................................... 121
National and International Presentations ........................................ 122
References .................................................................................. 123
List of tables

Table 2.1: Examples of manufacturing differences between first-generation moderately and highly cross-linked polyethylene used in total hip replacements ............................................................... 18

Table 2.2: in vivo standard-sized CoCr-on-Longevity PETM primary total hip replacement wear studies .......................................................... 33

Table 2.3: in vivo large CoCr-on-LongevityTM HXLPE articulation (±standard comparison) primary total hip replacement studies .................. 34

Table 2.4: The effect of different factors on cross-linked polyethylene wear generation .................................................................................. 40

Table 2.5: The effect of different factors on conventional PE wear generation .... 41

Table 2.6: Comparison of RSA and computer-assisted edge-detection techniques 45

Table 3.1: Variation in radiographic follow-up practices between countries ........ 68

Table 4.1: Demographic characteristics and component positioning for 28 mm and 36 mm patient cohorts .................................................................. 84

Table 4.2 Outer diameter of acetabular components by articulation size ............ 86

Table 4.3: Type of radiograph by articulation size ........................................ 86

Table 4.4: Variance in 2D FHP measurement, Bland–Altman limits of agreement and coefficient of variance for intra- and inter-observer measurements.......... 88

Table 4.5 Mean two-dimensional femoral head penetration (±95%CI) at different radiographic time points by articulation size ................................................. 90

Table 4.6: Two-dimensional wear rate (±SD) calculated from different reference time points and methods (2 decimal places) .............................................. 92

Table 4.7: Volumetric wear rate (±SD) calculated from different time points and methods by articulation size ................................................................. 95

Table 4.8: Mean wear rates (± SD) of 36 mm and 28 mm articulations using different radiographic time points and calculations ...................................................... 96

Table 4.9: Least square means for the effect of time on 2D FHP (mm) for 36 mm and 28 mm articulations ............................................................................... 100

Table 4.10: Least square means for both the effect of time (independent of articulation size) and articulation size (independent of time) on 2D FHP (mm) ........................................................................................................ 100

Table 4.11: Proportions of 36 mm and 28 mm Cohorts with 2DWR≥0.1 mm/yr and VWR≥80 mm³/yr ..................................................................................... 101
Table 4.12: Comparison of all patients with 2DWR ≥0.1 mm/yr (one-year-final radiograph by individual regression) compared with the overall cohort of patients <0.1 mm/yr................................................................................................................................. 103
Table 4.13: Demographic and component variables of 36 mm articulations with VWR ≥80 mm³/yr compared with <80 mm³/yr................................................................................................................................. 103
Table 4.14 Demographic and component variables of 28 mm articulations with VWR ≥80 mm³/yr compared with <80 mm³/yr................................................................................................................................. 104
List of figures

Figure 2.1: Schematic representation on role of radiation in achieving conversion from UHMWPE to XLPE ................................................................. 17
Figure 2.2: Relationship between change in the femoral head position (A, B, C in each scenario) and the observed 2D FHP over the serial time points analysed ................................................................. 23
Figure 2.3: Different modes of wear in THR articulations ......................... 38
Figure 2.4: Wear theory proposed by Charnley and Halley (1975) ............... 42
Figure 2.5: Examples of point selection (smaller, thicker circles) and resultant shadow-casting (thinner, larger circles) around an articulation using PolyWare™ ................................................................. 46
Figure 2.6: Display of the articulation modelling based upon data provided ........ 47
Figure 2.7: Implications of reporting mean wear rates only without regard to outliers exceeding the osteolysis threshold .............................................. 59
Figure 3.1: An example of a completed shadow cast following point entry and 3D model generated after entry into PolyWare™ of AP and lateral points, affirming acceptable point capture ................................................................. 71
Figure 3.2: Schematic representation of the preferred process of analysing 28 mm and 36 mm articulations in the current study using the PolyWare™ software .............................................................................................................. 72
Figure 3.3: Schematic example of the occurrence and correction of shadow cast error .............................................................................................................. 73
Figure 3.4: An example of 2D FHP (mm) outputs from 2 cycles of PolyWare™ analysis using the same patient radiograph sets .................................. 73
Figure 3.5: Schematic representation of possible wear rate slopes from use of three radiographic time points .............................................................................................................. 75
Figure 3.6: Schematic representation of individual regression for each patient ...... 75
Figure 3.7: Schematic representation of a cylindrical wear path relative to a PE liner .............................................................................................................. 80
Figure 3.8: Example of computer-assisted calculation of volumetric wear using a program based on the method of John Martell ........................................ 80
Figure 4.1: Representation of patients enrolled in RCT with either sufficient or insufficient radiograph sets for analysis .............................................. 84
Figure 4.2: Scatterplot of total 2D femoral head penetration (mm) plotted against postoperative time elapsed (months) .............................................. 89
Figure 4.3: Scatterplot of volumetric wear over time by the Charnley and Halley (1975) method with superimposed trendline through medians from 12 months for each cohort........................................................................................................91
Figure 4.4: Scatterplot of 2DWR calculated using individual regression (slope) of one-year to final radiograph for each patient ..........................................................93
Figure 4.5: Scatterplot of 2DWR calculated from individual regression using one-year to five-year radiographs..................................................................................93
Figure 4.6: Scatterplot of VWRs calculated by the regression of FHP using radiographs from 1 year to final each individual .................................................................97
Figure 4.7: Scatterplot of VWRs calculated using Martell (2014) method from 1-year to final radiographs for each individual .................................................................97
Figure 4.8: Scatterplot of VWRs calculated from individual regression using one- to five-year radiographs.........................................................................................98
Figure 4.9: Scatterplot of VWRs calculated using Martell (2014) method from one-to five-year radiographs for each individual .................................................................98
Figure 5.1: An example of a completed shadow cast following point entry and 3D model generated after entry into PolyWare™ of AP and lateral points, affirming acceptable point capture...........................................................112
Abstract

Total hip replacement is one of the most frequently performed and successful surgical procedures. Its most common modes of failure identified in joint registries are dislocation in the short term and aseptic loosening associated with wear and osteolysis in the long term. Therefore, the ideal articulation would have both a low incidence of dislocation and low wear.

Metal-on-highly cross-linked polyethylene (HXLPE) articulations of 36 mm diameter have been demonstrated in a randomised controlled trial to have a significantly lower incidence of dislocation at one year postoperatively compared to 28 mm articulations. Historically, large articulations (femoral head size ≥32 mm) have been associated with increased wear rates of conventional polyethylene compared to smaller articulations. Advances in polyethylene manufacture with cross-linking for clinical use in total hip replacements has significantly reduced early wear rates compared to conventional polyethylene. This has prompted reconsideration of the ideal femoral head size to enhance the longevity of articulations.

This study aims to compare the wear of 36 mm and 28 mm metal-on-highly cross-linked polyethylene total hip replacements through a post hoc analysis of radiographs of patients enrolled in the randomised controlled trial referred to above. Comparison of wear rates between cohorts was undertaken by use of computer-assisted analysis (PolyWare™) of patient radiograph sets.

Radiograph sets for 326 patients, 164 with 28 mm and 162 with 36 mm articulations, were analysed. 36 mm metal-on-HXLPE articulations were found to have a statistically significant higher magnitude of bedding-in and creep at three but not twelve months when compared to the 28 mm cohort. The mean annual two-dimensional wear rate from 1 year until final radiograph was 0.00mm/yr for both
cohorts. There were no differences between 36 mm to 28 mm cohorts in mean annual volumetric wear rates or significant differences in the proportion of patients in each cohort with two-dimensional wear rates ≥ 0.1 mm/yr or volumetric wear rates ≥ 80 mm³/yr. These wear rates have previously been associated with osteolysis when using metal-on-conventional polyethylene articulations.

While the use of large articulations had been reported to be associated with comparatively greater wear rates of articulations incorporating conventional PE, this appears not to apply to large articulations incorporating HXLPE. The low wear rates measured combined with the findings of the RCT of a significantly reduced incidence of dislocation at one year of 36mm compared to 28mm articulations, support the use of 36 mm metal-on-highly cross-linked polyethylene articulations. Longer term follow-up is required to assess whether low wear rates are maintained for both 36mm cohorts and whether wear of HXLPE is associated with the development of periprosthetic osteolysis.
Declaration

This manuscript contains no material that has been accepted for any other degree in any university. To the best of my knowledge and belief, this manuscript contains no material previously published or written by any other person, except where due reference is given in the text. I give my consent for this copy of my thesis, when deposited in the university library, being available for loan and photocopying as well as being available for access as part of the digital thesis program.

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28th August 2015
Acknowledgements

I would like to thank my supervisors, Dr Oksana Holubowycz and Professor Donald Howie, who provided guidance, expertise and assistance in this work. Mr Stuart Callary also provided substantial input into this work with specific expertise in radiographic measurement of polyethylene wear.

The efforts of surgeons, local study coordinators and all those involved in helping to coordinate the large head trial study group and in permitting involvement of patients in the study are highly appreciated.

I would also like to thank those who have contributed expertise and assistance in collation of the radiographs, information technology and patient material, including Susan Neale for her initial analysis guidance, Don Vivian for computer and software support and Caroline Moran for assisting in coordination of radiograph retrieval from the participating sites. Dr Nancy Briggs and Dr Stuart Howell from The University of Adelaide Data Management and Analysis Centre have provided assistance with statistical analysis. The professional editing service provided by Dr. Jill Pope and Mrs. Rosemary Purcell is acknowledged.

Financial assistance for aspects of the randomised controlled trial from where patient radiographs were drawn includes that provided by the Australian Orthopaedic Association, National Health and Medical Research Council, Royal Adelaide Hospital Research Foundation and Zimmer Australia. Subsequent help with logistics for courier service of radiographs by Zimmer Australia is also acknowledged with thanks.
I wish to acknowledge the patients who consented to participate in this research. Without their altruistic belief in clinical research, this study would not have been possible.

Violetta Zotti and my family have given an enormous amount of time, effort and compassion, which has enabled me to complete this work.
Abbreviations and glossary

2D  
two-dimensional

2DWR  
two-dimensional wear rates, analogous to linear wear rate

3D  
three-dimensional

annealing  
heating followed by gradual cooling applied to a material in an effort to allow recoil of polymer chains and relieve internal stresses

AOA NJRR  
Australian Orthopaedic Association National Joint Replacement Registry

AP  
antero-posterior

articulation  
Interface where mobility occurs between components of the THR

arthroplasty  
surgical modification of a native joint; in this thesis, this relates to total hip arthroplasty – replacement of the native joint with articulating prostheses

aseptic loosening  
debonding of the component-bone interface that is not the result of infection; associated with increased volumes of PE wear debris

bedding-in  
often discussed interchangeably or in combination with creep, but more strictly defined as loss of surface asperities left during manufacturing in the early postoperative period

BMI  
body mass index

CAD  
computer-assisted design

CAM  
computer-assisted manufacturing

CI  
confidence interval

CoCr  
cobalt chrome (will generally refer to the material used for metal femoral heads upon PE)

conventional polyethylene  
UHMWPE (non-cross-linked) utilised prior to the advent of cross-linking in the late 1990s

creep  
time-dependent deformation of a material under stress that does not produce wear particles. Non-wear generating process of creep and settling in of the liner that dominates initial observed FHP and includes
bedding-in. Often discussed interchangeably with bedding-in in the early postoperative period

CT
computed tomography

dislocation
an episode of disarticulation of the prosthetic joint
requiring reduction to restore joint mechanics

e-beam
electron beam (method of irradiation of PE
components, used exclusively by Zimmer™ in PE
manufacture)

FHP
femoral head penetration; FHP after creep-dominated
period may be referred to as steady-state linear wear

HXLPE
highly cross-linked polyethylene

in vitro
studies examining subjects outside their usual context;
relating to articulations studied in a laboratory context.

in vivo
studies examining outcome of interest in living subject;
in this context, relating to study of articulations
implanted into patients.

Initial radial discrepancy
the initial radius between the edge of a reduced femoral
head and the inner aspect of the acetabular component.
This discrepancy is deliberate on the part of component
manufacturer to ensure that manufacturing tolerances of
the components allow reduction.

large articulation
greater than or equal to 32 mm articulation

mg
milligrams

mm
millimetres

mm$^3$
cubic millimetres

Mrad
megarad (equivalent to 10 kilogram doses of radiation
energy)

negative wear
wear measurement over serial radiographs where the
vector changes from the expected direction; typically a
wear vector away from the acetabular component

osteolysis
resorption of bone in response to a pathology; in this
context caused by host response to PE wear particles

osteolysis threshold
threshold of annual wear rates in conventional PE
where osteolysis develops and below which osteolysis
is rare
periprosthetic relates to a process occurring around a prosthetic joint
PE polyethylene
phantom model a model of increments known to or adjusted by the
assessor used as a reference point to test measurement
tools with unknown performance
post hoc retrospective examination of data following conclusion
of the original part of a scientific process; implies that
the original experiment was not designed with outcome
of interest in mind
RCT randomised controlled trial
revision surgery undertaken subsequent to the primary (index)
surgical operation replacing some or all of the
components to address a problem that has since
developed
RSA Roentgen stereophotogrammetric analysis
standard articulation articulation sized less than 32 mm
SD standard deviation; square root of the variance from the
mean
steady-state linear wear FHP measured in the 2D plane following the bedding-in period
THR total hip replacement (primary unless otherwise stated)
TIFF tagged image file format
tribology the study of the interaction between bearing surfaces of
joints
UHMWPE ultra-high molecular-weight polyethylene
UK United Kingdom
USA United States of America
VWR volumetric wear rate
XLPE cross-linked polyethylene manufactured using at least
3 Mrad (i.e. includes moderately as well as highly
cross-linked PE)