

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.....	101
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: <i>in vivo</i> standard-sized CoCr-on-Longevity PE™ primary total hip replacement wear studies.....	33
Table 2.3: <i>in vivo</i> large CoCr-on-Longevity™ HXLPE articulation (\pm 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 (\pm 95%CI) at different radiographic time points by articulation size	90
Table 4.6: Two-dimensional wear rate (\pm SD) calculated from different reference time points and methods (2 decimal places).....	92
Table 4.7: Volumetric wear rate (\pm SD) calculated from different time points and methods by articulation size	95
Table 4.8: Mean wear rates (\pm 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 \geq 0.1 mm/yr and VWR \geq 80 mm ³ /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 mm ³ /yr compared with < 80 mm ³ /yr.....	103
Table 4.14 Demographic and component variables of 28 mm articulations with VWR ≥ 80 mm ³ /yr compared with < 80 mm ³ /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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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
<i>in vitro</i>	studies examining subjects outside their usual context; relating to articulations studied in a laboratory context.
<i>in vivo</i>	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 kilogray 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
<i>post hoc</i>	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)