BJR

■ HIP

Cemented Exeter total hip arthroplasty with a 32 mm head on highly crosslinked polyethylene

DOES AGE INFLUENCE FUNCTIONAL OUTCOME, SATISFACTION, ACTIVITY, STEM MIGRATION, AND PERIPROSTHETIC BONE MINERAL DENSITY?

N. D. Clement, M. Bardgett, K. Merrie, S. Furtado, R. Bowman, D. J. Langton, D. J. Deehan, J. Holland

Department of Orthopaedics, Freeman Hospital, Newcastle upon Tyne, United Kingdom.

■ N. D. Clement, PhD, FRCSEd(Tr&Orth), Academic Consultant,
■ M. Bardgett, BSc, MSc, Clinical Research Co-ordinator,
■ K. Merrie, BA (Hons), Project manager,
■ S. Furtado, PhD, BPTh, MSc, Senior Research Physiotherapist,
■ R. Bowman, DCR(R), BSc, Research assistant,
■ D. J. Deehan, MD, MSc, FRCS (Tr&Orth), DSc, Professor of Orthopaedics,
■ J. Holland, FRCS Orth, Orthopaedic Consultant, Department of Orthopaedics, Freeman Hospital, Newcastle upon Tyne, UK.
■ D. J. Langton, PhD, MRCS, Lead Clinical Scientist, Northern Retrieval Registry, The Biosphere, Newcastle Helix, Newcastle upon Tyne, UK.

Correspondence should be sent to N. D. Clement; email: nickclement@doctors.org.uk

doi: 10.1302/2046-3758.86.BJR-2018-0300.R1

Bone Joint Res 2019;8:275–287.

Objectives
Our primary aim was to describe migration of the Exeter stem with a 32 mm head on highly crosslinked polyethylene and whether this is influenced by age. Our secondary aims were to assess functional outcome, satisfaction, activity, and bone mineral density (BMD) according to age.

Patients and Methods
A prospective cohort study was conducted. Patients were recruited into three age groups: less than 65 years (n = 65), 65 to 74 years (n = 68), and 75 years and older (n = 67). There were 200 patients enrolled in the study, of whom 115 were female and 85 were male, with a mean age of 69.9 years (SD 9.5, 42 to 92). They were assessed preoperatively, and at three, 12 and, 24 months postoperatively. Stem migration was assessed using Einzel-Bild-Röntgen-Analyse (EBRA). Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Harris Hip Score (HHS), Hip Disability and Osteoarthritis Outcome Score (HOOS), EuroQol-5 domains questionnaire (EQ-5D), short form-36 questionnaire (SF-36,) and patient satisfaction were used to assess outcome. The Lower Extremity Activity Scale (LEAS), Timed Up and Go (TUG) test, and activPAL monitor (energy expelled, time lying/standing/walking and step count) were used to assess activity. The BMD was assessed in Gruen and Charnley zones.

Results
Mean varus/valgus tilt was -0.77^{o} and axial subsidence was -1.20 mm. No significant difference was observed between age groups ($p \geqslant 0.07$). There was no difference according to age group for postoperative WOMAC ($p \geqslant 0.11$), HHS ($p \geqslant 0.06$), HOOS ($p \geqslant 0.46$), EQ-5D ($p \geqslant 0.38$), patient satisfaction ($p \geqslant 0.05$), or activPAL ($p \geqslant 0.06$). Patients 75 years and older had a worse SF-36 physical function ($p = 0.01$) and physical role ($p = 0.03$), LEAS score ($p < 0.001$), a shorter TUG ($p = 0.01$), and a lower BMD in Charnley zone 1 ($p = 0.02$).

Conclusion
Exeter stem migration is within normal limits and is not influenced by age group. Functional outcome, patient satisfaction, activity level, and periprosthetic BMD are similar across all age groups.

Cite this article: *Bone Joint Res* 2019;8:275–287.

Keywords: Hip, Arthroplasty, Crosslinked, Cemented, Age, Outcome

Article focus
- To assess migration of the cemented Exeter stem using a relatively new bearing surface (32 mm head on highly crosslinked polyethylene) and whether this is influenced by age.
- We assessed functional outcome, patient satisfaction, activity, and bone mineral density according to age.

Key messages
- Stem migration is within normal limits and is not influenced by age group.

- Functional outcome, patient satisfaction, energy expenditure, activity duration, and step count after cemented total hip arthroplasty are not influenced by age.

Strengths and limitations

- A powered prospective cohort study with < 10% loss to follow-up.
- Short-term follow-up (24 months) is a limitation.

Introduction

The type of prosthesis used in primary total hip arthroplasty (THA) is influenced by the age and sex of the patient, with female patients and those over 65 years of age being more likely to receive a cemented prosthesis, while younger patients may receive uncemented designs.[1] Over the last decade, there has been an evolution in cementless fixation, crosslinked polyethylene, hard-on-hard bearings (metal and ceramic), and large-diameter head sizes. Despite generally higher costs and theoretical supporting data, some innovations have not performed as well as anticipated.[2] Registry data and clinical studies have demonstrated that the cemented Exeter THA (26 mm and 28 mm metal head on a non-crosslinked polyethylene socket) provides excellent function and long-term survival.[3,4] The long-term success of the cemented Exeter design has, therefore, emerged as the benchmark design.[5] Despite the cemented Exeter THA providing quality in terms of clinical performance with comparatively modest implant expenditure, polyethylene wear and dislocation remain problematic.

Ultra-high-molecular-weight polyethylene (UHMWPE) has been the preferred acetabular bearing material for over 30 years.[6] Performance and survivorship have been hindered by its inability to resist wear in the longer term.[7] Attempts to minimize this have led to the development of highly crosslinked polyethylene such as X3 (Stryker Orthopaedics, Mahwah, New Jersey), which has shown a reduction in volumetric wear rate when compared with conventional UHMWPE.[8] Younger patients or those who are more active could benefit from this bearing surface with a potentially increased survival rate of the implant.[9] Another benefit of this new polyethylene is that thinner components may be used, which in turn allows the use of larger head sizes and could lower the rate of dislocations.[10,11] Whether this new bearing surface and a larger head influences the stress upon the stem remains unknown.

The hypothesis of this study is that a cemented THA with a 32 mm head size and crosslinked polyethylene will result in a greater rate of stem migration and that this will be more prominent in younger patients who are potentially more active and who have greater functional demands and secondary increased periprosthetic bone mineral density (BMD). The primary aim of this study was to describe femoral stem migration in patients undergoing a cemented Exeter THA with a 32 mm head on a highly crosslinked polyethylene acetabular component and whether this is influenced by age. Secondary aims were to assess functional outcome, patient satisfaction, activity, and periprosthetic BMD after THA according to age.

Patients and Methods

During a 22-month period (July 2012 to April 2014), 200 patients listed for a THA at the study centre were prospectively identified and asked to enrol within the study. Inclusion criteria were: primary THA; primary diagnosis of non-inflammatory degenerative joint disease; and admitted to the study centre under the care of participating surgeons. Exclusion criteria were: refusal or inability to provide informed consent; revision THA; inflammatory joint disease; morbidly obese (body mass index (BMI) > 40 kg/m^2); patients unsuitable for a standard rim-fit socket design (whereby eccentric flange or other solution required); neuromuscular dysfunction of the trunk and lower limbs that may increase the dislocation rate and would limit the ability to assess the performance of the device, in which case the clinician may also prefer another device; inability to answer questionnaires for cognitive reasons; or patient requesting an alternative implant. Patients were originally categorized into four groups: less than 55 years; 55 to 64 years, 65 to 74 years; and 75 years and older. However, due to slow recruitment into the less than 55 years age group, this group was combined with those aged 55 to 64 years, and therefore this resulted in three groups: less than 65 years; 65 to 74 years; and 75 years and older.

Radiological outcomes measured. Einzel-Bild-Röntgen-Analyse-femoral component analysis (EBRA-FCA, University of Innsbruck, Austria) software was used to assess implant migration.[12] A single independent observer (RB) performed all radiological measurements. The EBRA-FCA software measures axial migration (millimetres), as well as tilting (^{0}), in the coronal plane. Standard anteroposterior pelvic radiographs were obtained postoperatively at three-, 12-, and 24-month follow-ups. The radiographs are calibrated using the known diameter of the femoral head. A total of 19 reference points were defined on the femoral head, stem, femoral cortex, and greater and lesser trochanters for the three consecutive radiographs.

The BMD was measured using dual-energy X-ray absorptiometry (DEXA) preoperatively and at three-, 12-, and 24-month follow-ups. Due to cost and ethical constraints (radiation exposure), a subgroup of 24 patients consented to undergo DEXA scans (less than 65 years (n = 7); 65 to 74 years (n = 7); 75 years and older (n = 10)). The BMD was assessed for each of the seven Gruen zones[13] of the femoral component, and the three DeLee and Charnley zones[14] for the acetabular component.

Functional outcomes measured. Validated patient-reported outcome measures were used to assess function preoperatively and postoperative at three, 12, and 24 months.

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)[15] used in this study was the Likert version 3.1, standardized with English for a British population. It consists of 24 self-administered questions that were answered using the 5-point Likert scale (none, mild, moderate, severe, and extreme). It was reported for the three separate subscales: pain; physical function; and stiffness. According to recent recommendations, scores for each subscale were reported from 0 (worst) to 100 (best).[16]

The Harris Hip Score (HHS) is a combined subjective and objective assessment that contains eight items representing pain, walking function, activities of daily living, and range of movement of the hip joint.[17] The collective score ranges from 0 (maximum disability) to 100 (no disability). The index consists of subjective questions relating to pain and activities of daily living over the previous week, and objective assessments of hip function and range of movement.

The Hip Disability and Osteoarthritis Outcome Score (HOOS) was used to assess hip specific quality of life, and each question was assessed using five Likert boxes (no, mild, moderate, severe, extreme).[18] All items were scored from 0 to 4 and each of the five subscales was calculated as the sum and transformed into a 0 (worst) to 100 (best) scale. This was reported as a separate scale, in addition to the WOMAC components.

The EuroQoL (EQ) general health questionnaire evaluates five domains (5D) which include mobility, self-care, usual activities, pain/discomfort, and anxiety/depression.[19] The 5L version of the EQ questionnaire was used, with the responses to the five domains being recorded at five levels of severity (no, slight problems, moderate, severe, or unable/extreme problems). An individual patient's health state can be reported based on a five-digit code for each domain, of which there are 3125 possible health states. Each health state was converted to a single summary index by applying a weighting. These are specific to the United Kingdom population and are based on a time trade-off technique. This index is on a scale of -1 to 1, where 1 represents perfect health, and 0 represents death. Negative values represent a state perceived as worse than death.

The short form-36 questionnaire (SF-36) is a generic health status measure that contains 36 items, and measures three major health attributes (functional status, wellbeing, and overall health).[20] There are eight subscales (physical function, role limitations due to physical health, bodily pain, general health, vitality, social function, role limitations due to emotional health, and mental health) that are ranked from 0 (worst) to 100 (best).

Patient satisfaction. Patient satisfaction was assessed at three, 12, and 24 months following surgery by asking four questions with a different focus: 1) "Overall how satisfied are you with the results of your hip replacement surgery?"; 2) "How satisfied are you with the results of your hip replacement surgery for improving your ability to do housework or yard work (such as cooking, cleaning, or gardening and raking leaves)?"; 3) "How satisfied are you with the results of your hip replacement surgery for improving your ability to do recreational activities (such as taking walks, swimming, bicycling, playing golf, dancing, going out with friends)?"; and 4) "How satisfied are you with the results of your hip replacement surgery for relieving your pain?"

The response to each question was recorded using the four-point Likert scale: very satisfied; somewhat satisfied; somewhat dissatisfied; and very dissatisfied. The focus of these questions has been previously determined by an expert consensus panel and was thought to reflect various facets of patient satisfaction.[21] These questions and the four-point Likert assessment have been validated and demonstrated to be reliable in measuring satisfaction after arthroplasty.[21]

Activity outcomes measured. Activity outcomes were assessed preoperatively and postoperatively at three, 12, and 24 months.

The lower extremity activity scale (LEAS) offers the patient one of 18 options that best describes their level of activity (Fig. a).[22] This ranges from 1, which is defined as "I am confined to my bed all day", which incrementally increases up to 18, which is defined as "I am up and about at will in my house and outside. I also participate in vigorous physical activity such as competitive level sports daily".

The Timed Up and Go (TUG) test was performed as originally described: the patient was timed while rising from an armchair (approximate seat height 46 cm), walking at a comfortable and safe pace to a line on the floor three metres away, turning and walking back to the chair and sitting down again.[23] The patient had a practice walk before the assessment to become familiar with the test. A faster time indicates a better functional performance.[23]

ActivPAL (PAL Technologies Ltd, Glasgow, United Kingdom) is a small uniaxial accelerometer and was used to record energy expelled (metabolic equivalents (METs) based on steps taken), time spent sitting/lying, standing, walking, and step counts for seven days.[24] These were assessed over a seven-day period and an average per-day value was then calculated for each of the assessment criteria.

Surgical procedure and implant. The surgery was performed or supervised by one of seven consultant surgeons (including JH). A posterior approach was used to approach the hip joint. A cemented Exeter stem was used for all with a 32 mm femoral head and an X3 (RimFit,

Table I. Significant adverse events after enrolment in the study for the first 24 months after total hip arthroplasty (THA)

Study ID	Brief description	Time from surgery, wks
017	Superficial wound infection	2
027	Dislocation	77
027	Dislocation	99
036	Falls secondary to bradycardia	51
052	Chest infection	57
072	Pneumonia and emphysema	Before surgery*
073	Haematoma and aspiration	2
073	Dislocation	8
073	Dislocation	13
073	Dislocation	94
086	Dislocation	22
097	Death (ischaemic heart disease)	83
120	Spinal pain	38
134	Suspected TIA	95
135	Death (gut ischaemia)	Before surgery
137	Pain right hip and pelvis	77
137	Dislocation	85
138	Leg swelling/suspected DVT	1
158	Shortness of breath	30
158	Catheter problems	76
165	Chest pain	34
181	Shortness of breath/collapsed	11
181	Falls	29
193	Falls	7
193	Back pain	56
200	Suspected hip fracture	1

*Patient was deemed not fit for surgery
TIA, transient ischaemic attack; DVT, deep vein thrombosis

Stryker Orthopaedics) cemented polyethylene socket (Stryker Orthopaedics). A standardized rehabilitation protocol was used for all patients, with active mobilization on the first day postoperatively.

Statistical analysis. Data analysis were performed using Statistical Package for Social Sciences version 17.0 (SPSS Inc., Chicago, Illinois). Student's *t*-test, paired and unpaired, and one-way analysis of variance (ANOVA) or the Kruskal–Wallis rank test, with *post hoc* Bonferroni's correction for multiple testing, were used to compare linear variables between groups. Dichotomous variables were assessed using a chi-squared test. Spearman's rank correlation coefficient was used to assess the association between the LEAS (ordinal) and step count. A p-value of < 0.05 was defined as significant.

The study was powered to assess the primary outcome of stem subsidence using EBRA-FCA, which is thought to be accurate to ± 1.5 mm.[12] To achieve a power of 0.95 and an alpha of 0.05 with correction for multiple testing (Bonferroni's) of the three groups using a known SD of 1.4,[25] it was calculated that 37 patients would need to be recruited to each group, i.e. 111 patients in total. There were 200 patients enrolled in the study, of whom 115 were female and 85 were male, with a mean age of 69.9 years (SD 9.5, 42 to 92).

Results

Significant adverse events were recorded for all patients enrolled in the study (Table I). There were four dislocations (two in the 65 to 74 years group and two in the 75 years and older group), which was not significantly different according to the age group ($p = 0.39$). Five patients were excluded prior to surgery (Fig. 1). Of the remaining 195 patients, 64 were less than 65 years, 67 were 65 to 74 years, and 64 were 75 years and older, and there were no significant ($p = 0.24$) differences in sex between the groups (male patients n = 32, n = 43, and n = 40 respectively).

Radiological outcomes. There was no significant difference in EBRA for varus/valgus tilt or axial subsidence between the groups (Table II), with an overall mean varus/valgus tilt of -0.77^0 (SD 0.03) and axial subsidence of -1.20 mm (SD 1.21). There were no significant differences in the Gruen zones between the groups, except for zone 2 at 24 months where those patients less than 65 years had a significantly lower BMD than those 75 years and older. There was a significantly lower BMD in DeLee and Charnley zone 1 at three, 12 and, 24 months for the 75 years and older group when compared with younger age groups (Fig. 2), but this was not observed for zones 2 and 3 (Table II).

Functional outcomes. All groups had significant improvements in all of the functional outcome measures assessed (ANOVA, $p < 0.001$; Tables III and IV). There was no significant difference in the postoperative WOMAC scores, HHS, HOOS, EQ-5D or for the bodily pain, general health, vitality, social function, emotional role, and mental health components of the SF-36 at any assessment point (Tables III and IV). Interestingly, physical function (Fig. 3) and role components of the SF-36 were significantly greater at 12 and 24 months for the less than 65 years group when compared with the 75 years and older group (Table IV).

Patient satisfaction. There was no significant difference in patient satisfaction with pain relief, work, recreation, or overall outcome between the groups (Table V). There was a trend towards a greater percentage of satisfaction in the 75 years and older group at three months; however by 12 and 24 months the rates were similar, with > 91% of patients being satisfied with pain relief, work, recreation, and overall outcome.

Activity outcomes. The 75 years and older group had a significantly lower (worse) LEAS and a longer TUG test time (Fig. 4) than those in the less than 65 years group (Table VI). However, the 75 years and older group had a significantly greater improvement ($p < 0.001$; 13.2 seconds) in their TUG test at 24 months when compared with the less than 65 years (5.0 seconds) and the 65 to 74 years (3.6 seconds) groups. There were no significant differences in postoperative energy expelled, time to sit/lie, stand, walk, or step counts between the groups (Table VI). Step count preoperatively was shown to correlate significantly ($r = 0.60$; $p < 0.001$; Pearson's correlation coefficient) with step count at one year, with a similar trend being observed for all age groups (Fig. 5). There was a significant correlation between the LEAS

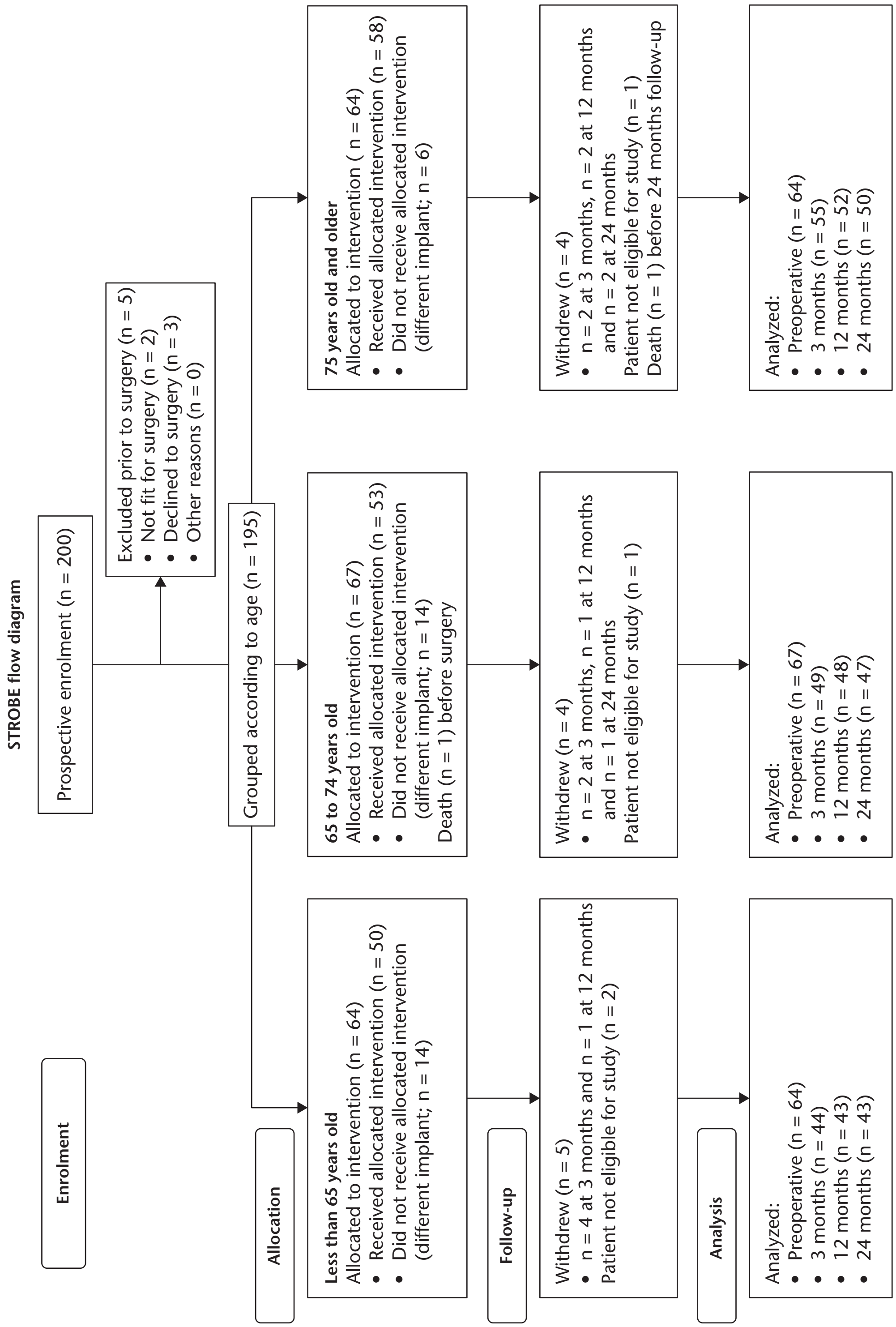

Fig. 1

Strengthening the Reporting of Observational studies in Epidemiology (STROBE) flow diagram for the study cohort.

Table II. Radiological assessments after total hip arthroplasty according to age group

Radiological assessment	Timepoint, mths	n	< 65 yrs	65 to 74 yrs	≥ 75 yrs	p-value*
EBRA						
Mean varus/valgus tilt, ° (SD)	3	139	0.14 (2.78)	-1.11 (2.87)	-1.01 (2.79)	0.08†
	12	135	-0.12 (3.09)	-1.11 (3.09)	-1.33 (2.85)	0.14†
	24	120	0.30 (3.11)	-1.22 (2.92)	-1.24 (2.91)	0.07†
Mean axial subsidence, mm (SD)	3 to 12	133	-0.78 (0.90)	-0.70 (0.95)	-0.56 (0.68)	0.48†
	3 to 24	111	-1.21 (1.03)	-1.24 (1.39)	-1.14 (1.20)	0.93†
Mean BMD, % (SD)						
Gruen zone 1	3	23	*11.0* (10.0)	*16.1* (19.7)	*6.4* (10.4)	0.40
	12	23	*9.5* (18.2)	*20.4* (37.7)	*12.5* (24.9)	0.75
	24	22	*4.0* (12.7)	*13.5* (28.5)	*8.3* (15.4)	0.67
Gruen zone 2	3	24	*-4.7* (8.8)	*-1.0* (7.4)	*-1.7* (12.4)	0.76
	12	24	*-8.9* (7.9)	*3.8* (16.8)	*11.1* (19.7)	0.06
	24	22	*-14.5* (12.9)	*-1.4* (12.8)	*13.1* (28.1)	0.04‡
Gruen zone 3	3	23	*-5.9* (6.4)	*-1.3* (17.6)	*-2.9* (15.8)	0.84
	12	23	*-6.5* (9.4)	*5.2* (27.4)	*0.6* (14.6)	0.50
	24	21	*-13.6* (10.6)	*-1.3* (21.5)	*2.1* (31.0)	0.41
Gruen zone 4	3	24	*-4.9* (7.0)	*7.3* (15.2)	*-2.4* (9.9)	0.11
	12	24	*-2.9* (8.6)	*10.0* (16.9)	*-3.5* (36.2)	0.53
	24	22	*-3.2* (6.7)	*4.4* (17.1)	*4.3* (22.8)	0.64
Gruen zone 5	3	23	*-9.9* (9.3)	*-6.1* (10.6)	*-12.5* (10.2)	0.46
	12	23	*-0.6* (17.2)	*-5.5* (9.8)	*-6.9* (9.3)	0.59
	24	21	*-0.4* (20.6)	*-10.8* (14.1)	*0.2* (40.9)	0.71
Gruen zone 6	3	24	*-15.4* (11.9)	*-18.6* (15.0)	*-10.4* (11.1)	0.42
	12	24	*-9.9* (11.6)	*-21.3* (10.2)	*-13.2* (8.6)	0.11
	24	22	*-21.8* (16.4)	*-21.8* (11.1)	*0.19* (41.1)	0.21
Gruen zone 7	3	24	*0.2* (20.1)	*16.1* (13.2)	*9.7* (32.0)	0.49
	12	24	*-5.3* (20.6)	*17.0* (25.5)	*10.6* (31.1)	0.30
	24	22	*3.7* (49.5)	*-2.1* (20.4)	*5.3* (33.3)	0.93
Charnley zone 1	3	23	*11.0* (21.5)	*20.9* (22.0)	*-18.3* (17.2)	0.03§
	12	21	*19.8* (35.1)	*33.7* (30.7)	*-21.9* (25.9)	0.04§
	24	20	*8.3* (29.9)	*38.0* (34.4)	*-9.2* (15.7)	0.02¶
Charnley zone 2	3	20	*13.4* (16.0)	*25.5* (25.4)	*13.1* (14.8)	0.43
	12	22	*11.9* (18.3)	*16.5* (25.0)	*13.0* (13.7)	0.90
	24	21	*14.5* (12.4)	*66.6* (17.7)	*19.2* (19.3)	0.32
Charnley zone 3	3	23	*3.2* (24.3)	*-5.0* (23.5)	*-3.6* (24.5)	0.81
	12	24	*-1.0* (27.3)	*-7.5* (23.5)	*-15.4* (9.6)	0.36
	24	22	*-1.5* (21.5)	*-11.4* (28.8)	*-7.5* (19.0)	0.73

*ANOVA test unless otherwise highlighted.
†Kruskal–Wallis rank test.
‡Statistically significant between less than 65 years and 75 years and older only
§Statistically significant between less than 65 years and 75 years and older, and between 65 to 74 years and 75 years and older
¶Statistically significant between 65 to 74 years and 75 years and older only
EBRA, Einzel-Bild-Röntgen-Analyse; BMD, bone mineral density

and step count preoperatively ($r = 0.53$; $p < 0.001$; Spearman's rank correlation coefficient) (Fig. 6), at three months ($r = 0.43$; $p < 0.001$; Spearman's), at 12 months ($r = 0.40$; $p = 0.002$; Spearman's), and at 24 months ($r = 0.36$; $p = 0.02$; Spearman's) (Fig. 7).

Discussion

This study has shown no difference in cemented stem migration when assessed by EBRA according to age group. Interestingly, joint-specific functional outcome was not influenced by age, as defined by groups, but overall generic physical function and role were worse in the 75 years and older group after THA. Patient satisfaction, energy expelled, time lying/sitting, time standing, time walking, and step rate were not influenced by age after THA. However, subjective (LEAS) assessment of activity highlighted a lower level of activity in those 75 years and older and a longer TUG test when compared with those less than 65 years old. With the exception of DeLee and Charnley zone 1, there was no significant difference in periprosthetic BMD between the age groups.

A limitation of this study was the defined age groups, as some surgeons may suggest that patients less than 50 years old have different outcomes to older groups. The original study aimed to have four groups, which would have required 260 patients to be recruited. However, recruitment of patients aged less than 55 years old was slow. There may be several reasons for this: surgeon equipoise; indication for THA; meeting inclusion/exclusion criteria; forming a relatively small proportion of patients undergoing THA at the centre; and younger, physically fitter patients may have been placed on waiting list initiatives outwith the NHS. The three defined age groups used in this study form representative thirds according to age. The mean age of patients undergoing THA in the United Kingdom is approximately 70 years (SD 10),[26] therefore half the SD either side of the mean would capture 34% of patients and was used to define

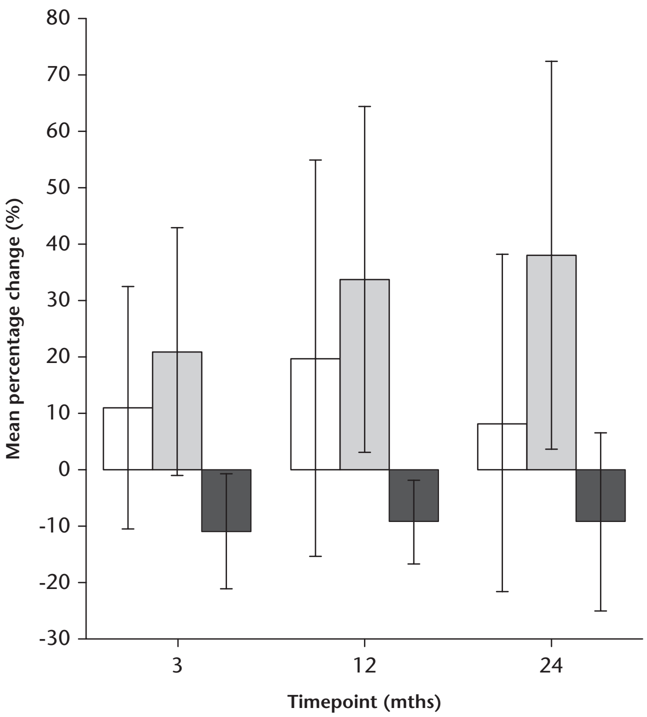

Fig. 2

Percentage change in bone mineral density (BMD) compared with the preoperative measure for DeLee and Charnley zone 1 at three, 12, and 24 months for those less than 65 years (white), 65 to 74 years (light grey), and 75 years and older (dark grey).

the 65 to 74 years group. The 33% of patients either side of the 65 to 74 years group undergoing THA was then used to define the other two groups. A second limitation was the dropout rate of 26% (n = 52) after recruitment. However, the main reason for this was either the patient did not undergo surgery (n = 5) or did not receive the allocated implant (n = 34). Of the 34 patients who received a different implant, their preoperative demographics and functional scores were no different to the study cohort ($p > 0.1$). Of the 161 patients who received the correct implants, only 13 patients (8%) withdrew from the study during follow-up to 24 months (Fig. 1).

The Exeter stem (Stryker Orthopaedics) relies on a force closed system with controlled subsidence at the interface between the implant and cement.[27,28] The polished stem allows for settling without the creation of debris from friction, which is thought to distribute an even stress across the cement mantle.[29] Two minor adaptations to the conventional Exeter system have been used in this study, both with the potential advantages of reduced wear with a crosslinked polyethylene socket and lower dislocation rate with an increased head size of 32 mm.[8,11] Increasing head size can increase sliding distance and frictional torque applied to the stem. This study has demonstrated, using EBRA-FCA, that stem varus/valgus (mean -0.77^{o} (SD 3.03)) and subsidence (mean -1.20 mm (SD 1.21)) are within acceptable limits.[30,31] However, no defined subsidence cut point exists for predicting failure of the Exeter stem, but accepted values of between 0.7 mm and 1.67 mm have been reported.[27,28] In addition, the current study found no association of stem tilt or subsidence between the age

Table III. Functional measures pre- and postoperatively according to age group

Mean score (SD)	Timepoint	n	< 65 yrs	65 to 74 yrs	≥ 75 yrs	p-value*
WOMAC (pain)	Preoperative	192	31.3 (17.2)	37.8 (21.3)	39.5 (18.5)	0.052
	3 mths	141	79.7 (22.4)	87.4 (14.3)	85.7 (15.7)	0.13
	12 mths	140	89.3 (13.6)	88.8 (15.0)	91.5 (14.2)	0.62
	24 mths	130	89.5 (18.6)	92.8 (11.8)	84.7 (22.1))	0.11
WOMAC (stiffness)	Preoperative	188	34.1 (21.0)	38.5 (24.1)	44.9 (23.3)	0.03†
	3 mths	140	71.4 (20.2)	78.6 (14.7)	76.4 (17.7)	0.15
	12 mths	136	84.2 (18.5)	83.8 (18.4)	82.8 (19.0)	0.93
	24 mths	127	81.4 (23.9)	86.6 (19.0)	80.3 (23.7)	0.37
WOMAC (function)	Preoperative	189	32.8 (17.5)	37.2 (21.1)	39.1 (17.2)	0.16
	3 mths	134	76.5 (20.5)	80.4 (15.2)	75.3 (17.4)	0.39
	12 mths	142	87.8 (15.5)	84.1 (17.3)	81.6 (20.4)	0.24
	24 mths	132	86.8 (20.4)	84.0 (19.8)	81.5 (21.5)	0.48
HHS	Preoperative	177	47.7 (12.8)	50.1 (15.0)	45.4 (13.3)	0.19
	3 mths	129	79.2 (15.8)	78.5 (15.8)	72.2 (13.4)	0.15
	12 mths	125	88.8 (14.0)	85.4 (14.6)	80.3 (19.2)	0.06
	24 mths	134	87.9 (17.8)	89.2 (11.0)	81.4 (18.1)	0.07
HOOS	Preoperative	192	24.4 (15.3)	28.9 (17.4)	27.8 (16.3)	0.28
	3 mths	145	62.9 (22.3)	62.5 (17.7)	63.5 (18.8)	0.97
	12 mths	137	77.8 (21.1)	76.1 (19.7)	81.3 (20.2)	0.46
	24 mths	132	79.8 (18.1)	78.4 (19.9)	80.0 (25.2)	0.93
EQ-5D	Preoperative	194	0.29 (0.12)	0.32 (0.11)	0.46 (0.23)	0.53
	3 mths	145	0.79 (0.16)	0.82 (0.17)	0.63 (0.13)	0.38
	12 mths	140	0.66 (0.14)	0.84 (0.19)	0.79 (0.22)	0.53
	24 mths	135	0.84 (0.22)	0.66 (0.14)	0.60 (0.13)	0.57

*ANOVA test
†Statistically significant between less than 65 years and 75 years and older only
WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; HHS, Harris Hip Score; HOOS, Hip Disability and Osteoarthritis Outcome Score; EQ-5D, EuroQol-5 domains questionnaire

Table IV. Short form-36 questionnaire (SF-36) measures pre- and postoperatively according to age group

Component (mean, SD)	Timepoint	n	< 65 yrs	65 to 74 yrs	⩾ 75 yrs	p-value*
Physical function	Preoperative	191	22.7 (15.4)	28.1 (20.2)	19.3 (18.0)	0.02†
	3 mths	140	63.8 (26.1)	65.3 (25.1)	47.1 (24.6)	0.004‡
	12 mths	141	74.2 (27.7)	63.4 (30.3)	50.5 (31.4)	0.001§
	24 mths	132	72.7 (28.0)	64.5 (30.0)	54.2 (29.1)	0.01§
Physical role	Preoperative	187	27.2 (24.3)	30.7 (26.5)	30.1 (25.3)	0.71
	3 mths	137	57.6 (28.6)	58.9 (26.8)	52.3 (26.7)	0.74
	12 mths	137	79.1 (28.6)	70.6 (29.9)	59.4 (32.3)	0.007§
	24 mths	129	77.7 (31.1)	65.6 (34.4)	59.0 (33.5)	0.03§
Bodily pain	Preoperative	191	20.4 (13.1)	30.2 (22.0)	28.1 (20.2)	0.01¶
	3 mths	142	58.8 (24.0)	67.8 (21.0)	63.3 (22.8)	0.18
	12 mths	141	70.9 (27.1)	67.1 (25.4)	62.9 (29.5)	0.37
	24 mths	131	68.4 (30.1)	63.5 (27.1)	58.7 (28.8)	0.31
General health	Preoperative	180	57.7 (24.8)	67.6 (24.8)	62.6 (19.4)	0.07
	3 mths	140	71.2 (20.3)	72.6 (17.0)	69.0 (14.2)	0.58
	12 mths	131	67.2 (22.6)	65.0 (23.1)	67.9 (17.6)	0.81
	24 mths	126	68.6 (24.6)	68.5 (22.8)	65.2 (22.0)	0.74
Vitality	Preoperative	190	33.2 (22.9)	45.8 (23.1)	40.2 (21.9)	0.06¶
	3 mths	138	53.4 (21.5)	59.0 (21.5)	53.0 (17.9)	0.30
	12 mths	141	63.4 (23.1)	58.2 (21.5)	54.0 (23.6)	0.14
	24 mths	129	63.5 (22.6)	62.9 (21.3)	56.2 (19.7)	0.20
Social function	Preoperative	191	45.8 (26.7)	54.3 (31.2)	45.1 (29.4)	0.14
	3 mths	142	76.9 (27.6)	80.5 (27.9)	70.8 (30.4)	0.25
	12 mths	142	83.8 (27.3)	84.2 (26.0)	72.6 (32.9)	0.08
	24 mths	135	82.1 (27.2)	80.4 (30.0)	72.9 (31.7)	0.29
Emotional role	Preoperative	187	64.3 (32.5)	67.1 (38.4)	59.8 (37.8)	0.54
	3 mths	141	75.6 (30.8)	81.7 (27.3)	73.8 (29.4)	0.40
	12 mths	138	90.7 (18.5)	85.6 (25.5)	79.2 (27.7)	0.08
	24 mths	125	85.4 (27.9)	80.3 (31.9)	74.6 (29.5)	0.28
Mental health	Preoperative	189	64.2 (21.4)	71.8 (20.3)	70.0 (20.0)	0.10
	3 mths	138	72.7 (19.7)	78.5 (18.5)	75.9 (16.0)	0.34
	12 mths	141	77.9 (20.9)	79.3 (16.7)	76.4 (18.6)	0.76
	24 mths	129	78.1 (15.4)	77.5 (18.7)	77.2 (17.3)	0.98

*ANOVA test
†Statistically significant between 65 to 74 years and 75 years and older only
‡Statistically significant between less than 65 years and 75 years and older, and between 65 to 74 years and 75 years and older
§Statistically significant between less than 65 years and 75 years and older only
¶Statistically significant between less than 65 years and 65 to 74 years only

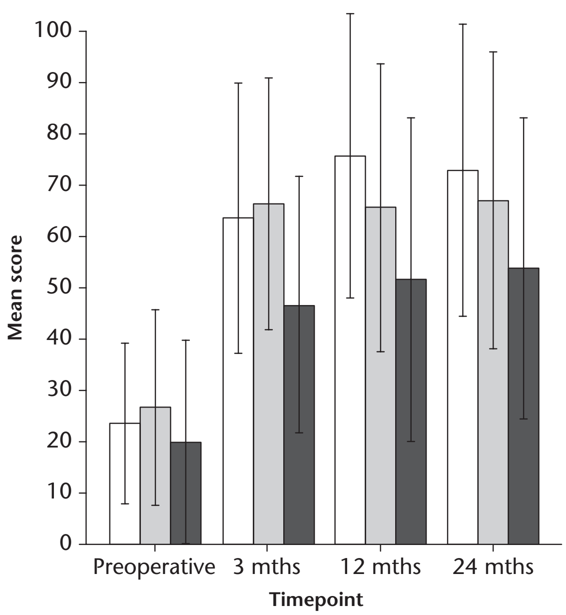

Fig. 3

Physical function component of the short form-36 questionnaire (SF-36) preoperatively and at three, 12 and 24 months for those less than 65 years (white), 65 to 74 years (light grey), and 75 years and older (dark grey).

groups assessed, which supports the use of the cemented Exeter stem in all age groups. The reported BMD in Gruen zones is similar to that of an Exeter stem with a 28 mm metal head on UHMWPE,[32] which indicates no change in stress loading in the proximal femur with a larger head and different bearing surface. The current study also found no evidence of stress shielding in DeLee and Charnley zones 1 or 2, in which there was an actual increase in BMD of 6% and 15%, respectively, due to the highly crosslinked polyethylene, which is a novel finding. The reason why there was a significant decrease in BMD in zone 1 at 24 months in the 75 years and older group compared with those in the other two groups is not clear. This may represent a type I error, but there was also a significant difference at three and 12 months between the 75 years and older group and the less than 65 years old group.

There is conflicting evidence as to the influence of age upon the functional outcome after THA.[33] The current study demonstrated no significant difference according to age group for hip-specific measures assessed (WOMAC, HHS, HOOS). This is supported by Judge et al[34] and Clement et al[35] using the Oxford Hip Score,

Table V. Satisfaction after total hip arthroplasty according to age group

Satisfaction, n (%)	Timepoint, mths	Satisfied	< 65 yrs	65 to 74 yrs	≥ 75 yrs	p-value*
Pain	3	Yes (n = 141)	42 (91.3)	45 (97.8)	54 (100)	0.05
		No (n = 5)	4 (8.7)	1 (2.2)	0 (0)	
	12	Yes (n = 134)	42 (97.7)	44 (100)	48 (96.0)	0.42
		No (n = 3)	1 (2.3)	0 (0)	2 (4.0)	
	24	Yes (n = 121)	36 (91.1)	43 (97.7)	42 (93.3)	0.51
		No (n = 5)	1 (8.9)	1 (2.3)	3 (6.7)	
Work	3	Yes (n = 131)	41 (91.1)	43 (93.5)	47 (97.9)	0.36
		No (n = 8)	4 (8.9)	3 (6.5)	1 (2.1)	
	12	Yes (n = 130)	43 (100)	40 (90.9)	47 (94.0)	0.15
		No (n = 7)	0 (0)	4 (9.1)	3 (6.0)	
	24	Yes (n = 118)	36 (97.3)	41 (93.2)	41 (91.1)	0.51
		No (n = 8)	1 (2.7)	3 (6.8)	4 (8.9)	
Recreation	3	Yes (n = 127)	39 (88.6)	43 (93.5)	45 (95.7)	0.42
		No (n = 10)	5 (11.4)	3 (6.5)	2 (4.3)	
	12	Yes (n = 124)	40 (95.2)	41 (91.1)	43 (87.8)	0.46
		No (n = 12)	2 (4.8)	4 (8.9)	6 (12.2)	
	24	Yes (n = 114)	35 (94.6)	41 (93.2)	38 (86.4)	0.36
		No (n = 11)	2 (5.4)	3 (6.8)	6 (13.6)	
Overall	3	Yes (n = 141)	43 (93.5)	44 (97.8)	54 (100)	0.14
		No (n = 4)	3 (6.5)	1 (2.2)	0 (0)	
	12	Yes (n = 134)	41 (95.3)	44 (97.8)	49 (98.0)	0.71
		No (n = 3)	2 (4.7)	1 (2.2)	1 (2.0)	
	24	Yes (n = 123)	35 (94.6)	43 (97.7)	45 (97.8)	0.65
		No (n = 4)	2 (5.4)	1 (2.3)	1 (2.2)	

*Chi-squared test

also a hip-specific measure, finding the effect of age was less than the minimally important clinical difference. The difference found in the SF-36 scores for physical function and physical role, with patients 75 years and older having significantly worse scores, has been observed previously after THA.[35,36] This difference in the overall generic physical health of younger *versus* older patients is thought to be due to ageing and overall physical deterioration with ageing. Despite the lower overall generic physical health scores after THA, older patients have been shown to have a significantly greater rate of patient satisfaction.[35] The current study did not demonstrate a significant difference in satisfaction rate between the age groups, but patients 75 years and older had a 3% greater rate of overall satisfaction than those less than 65 years old.

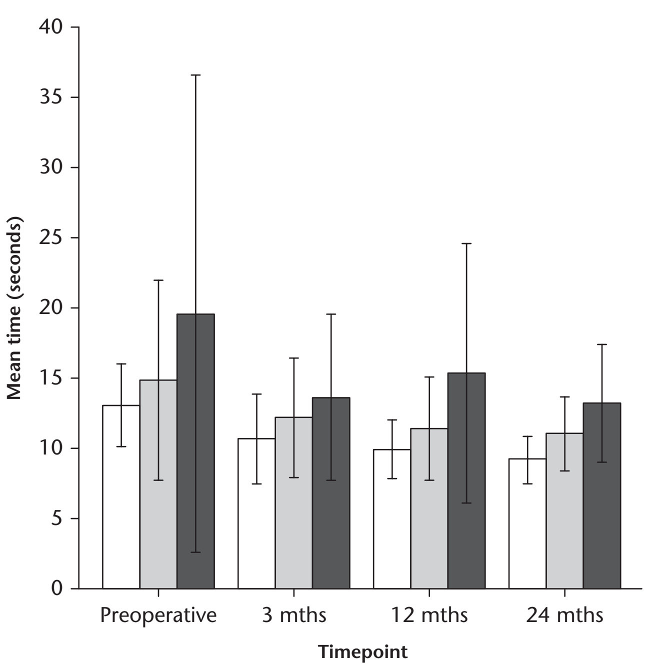

Fig. 4

Timed Up and Go (TUG) test preoperatively and at three, 12, and 24 months for those less than 65 years (white), 65 to 74 years (light grey), and 75 years and older (dark grey).

Assessment of activity after THA, according to age, was a novel aspect of this study. Subjective assessment of activity 24 months after THA using the LEAS demonstrated that, on average, the 75 years and older group defined their activity as: "I am up and about at will in my house and can go out and walk as much as I would like with no restrictions (weather permitting)". In contrast, the less than 65 years and 65 to 74 years groups, on average, defined their activity as: "I am up and about at will in my house and outside. I also work outside the house in an extremely active job". The LEAS was demonstrated to correlate with step count at all timepoints, suggesting that this is a subjective marker of activity level. However, objective postoperative assessment of energy expelled, time lying/sitting, time standing, and time walking or step counts were not significantly different between the age groups after THA. This finding is supported by Jeldi et al[37] who found function, according to the HHS, to be the main predictor of activity but not absolute age. In fact, pre- and postoperative activity times have been shown not to change after THA, which is thought to be due to fixed lifestyle choices.[38] Interestingly, the only

Table VI. Activity assessments pre- and postoperatively according to age group

Activity assessment	Timepoint	n	< 65 yrs	65 to 74 yrs	≥ 75 yrs	p-value*
Mean LEAS (SD)	Preoperative	193	8.7 (2.4)	7.9 (2.6)	7.5 (2.2)	0.02†
	3 mths	147	10.0 (2.6)	8.9 (2.3)	7.9 (2.0)	< 0.001†
	12 mths	140	12.5 (2.8)	11.5 (2.9)	8.7 (2.9)	< 0.001†
	24 mths	135	12.0 (3.1)	11.6 (3.2)	9.0 (3.0)	< 0.001†
Mean TUG, s (SD)	Preoperative	189	16.0 (11.7)	14.9 (6.1)	26.5 (35.9)	0.03†
	3 mths	141	11.8 (6.2)	12.3 (4.1)	14.9 (6.5)	0.03†
	12 mths	124	9.9 (2.0)	11.9 (4.1)	17.1 (12.6)	0.001†
	24 mths	114	9.0 (1.8)	11.3 (2.9)	13.3 (4.0)	0.01‡
Mean energy expelled, MET (SD)	Preoperative	95	32.8 (1.3)	32.3 (1.4)	31.7 (0.9)	0.04†
	3 mths	69	32.4 (1.3)	32.5 (1.4)	31.9 (1.0)	0.24
	12 mths	58	31.1 (1.4)	32.2 (1.7)	31.4 (1.4)	0.11
	24 mths	41	30.4 (1.2)	31.1 (1.5)	29.9 (1.5)	0.57
Mean time sitting/lying, hrs (SD)	Preoperative	95	18.9 (1.8)	18.4 (2.7)	19.3 (3.1)	0.40
	3 mths	69	19.2 (1.7)	18.5 (2.5)	19.1 (2.1)	0.53
	12 mths	58	18.3 (2.2)	17.6 (2.9)	18.5 (1.3)	0.44
	24 mths	41	18.6 (2.0)	17.6 (2.7)	18.1 (1.3)	0.50
Mean time standing, hrs (SD)	Preoperative	95	3.9 (1.5)	4.5 (2.3)	4.0 (3.1)	0.58
	3 mths	69	3.7 (1.5)	4.4 (2.0)	4.1 (1.9)	0.41
	12 mths	58	3.4 (1.6)	4.3 (2.2)	3.8 (1.0)	0.27
	24 mths	41	3.0 (1.3)	4.0 (2.3)	3.3 (0.8)	0.33
Mean time walking, hrs (SD)	Preoperative	95	1.2 (0.6)	1.0 (0.7)	0.6 (0.4)	0.04†
	3 mths	69	1.1 (0.5)	1.1 (0.6)	0.8 (0.4)	0.08
	12 mths	58	1.2 (0.5)	1.3 (0.7)	1.0 (0.4)	0.25
	24 mths	41	1.0 (0.6)	1.2 (0.6)	0.9 (0.4)	0.43
Mean step count, n (SD)	Preoperative	95	5583 (3211)	4501 (3273)	2740 (1977)	0.001†
	3 mths	69	5251 (2644)	4762 (3010)	3305 (2122)	0.06
	12 mths	58	5370 (2524)	6071 (3256)	4344 (2195)	0.15
	24 mths	41	4269 (2905)	5760 (3199)	3915 (2054)	0.56

*ANOVA test
†Statistically significant between less than 65 years and 75 years and older only
‡Statistically significant between all groups
LEAS, lower extremity activity scale; TUG, Timed Up and Go; MET, metabolic equivalent

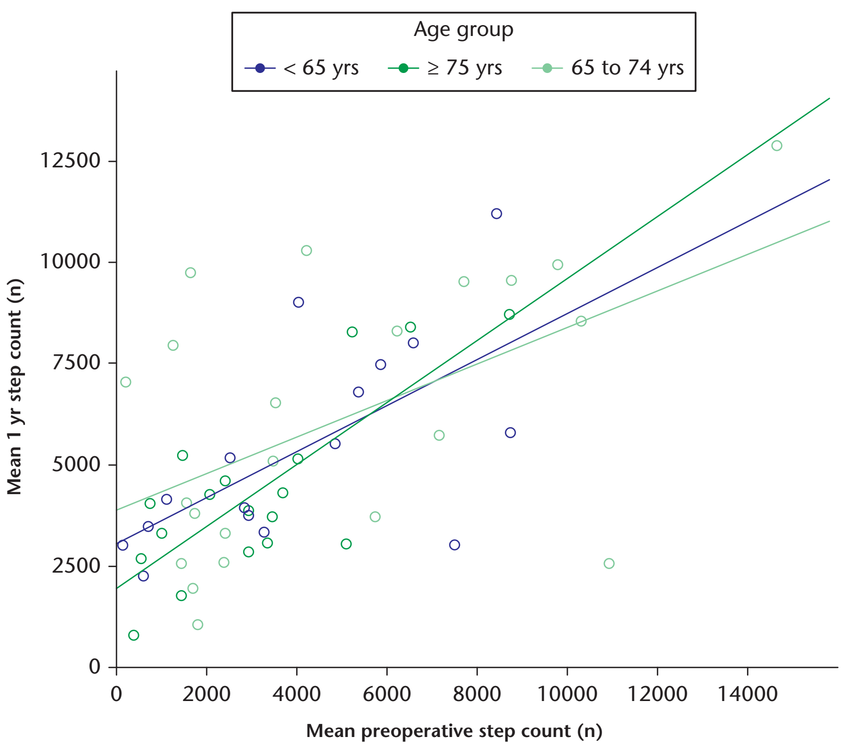

Fig. 5

Scatter plot with line of best fit (linear) according to age group between the preoperative step count and one year postoperative step count.

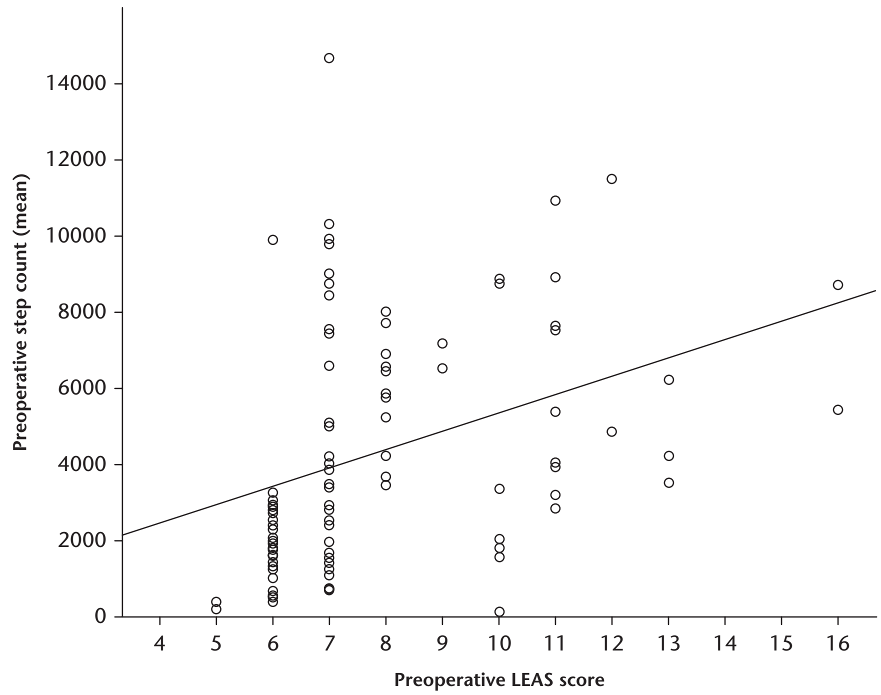

Fig. 6

Scatter plot with line of best fit (linear) between the preoperative lower extremity activity scale score and preoperative step count.

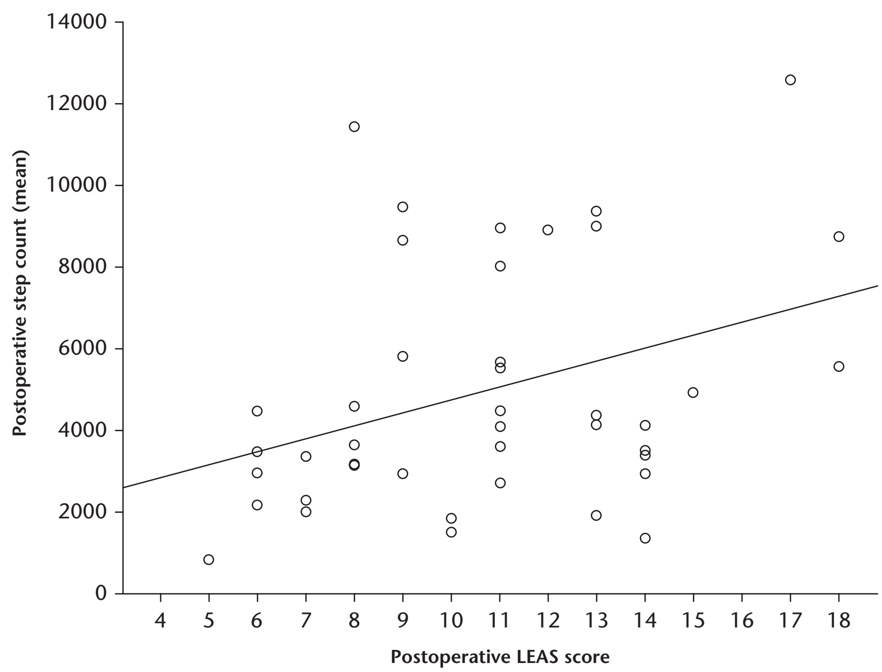

Fig. 7

Scatter plot with line of best fit (linear) between the 2 years postoperative lower extremity activity scale score and 2 years postoperative step count.

objective test to be significantly different between the age groups was the TUG test, with older groups having a longer TUG time. This may reflect the overall physical function of the patients, rather than their hip-specific function, as the SF-36 physical function and role scores were significantly worse in those 75 years and older, while there was no difference in hip-specific function according to age. The SF-36 physical function and physical role have been shown to correlate with the TUG test and may explain why this is longer in the older age groups, due to other physical limitations, may not be a marker of hip function but of overall physical health.[39]

In conclusion, the rate of stem migration with a 32 mm head size on crosslinked polyethylene is within normal limits and is not influenced by age group. Functional outcome, satisfaction, activity level, and periprosthetic BMD are similar across all age groups.

Supplementary material

Figure showing the lower extremity activity scale (LEAS), which assesses a patient's activity level preoperatively and postoperatively at three, 12, and 24 months.

References

1. **Kallala R, Anderson P, Morris S, Haddad FS.** The cost analysis of cemented versus cementless total hip replacement operations on the NHS. *Bone Joint J* 2013;95-B:874-876.
2. **Sedrakyan A, Normand SL, Dabic S, et al.** Comparative assessment of implantable hip devices with different bearing surfaces: systematic appraisal of evidence. *BMJ* 2011;343:d7434.
3. **Malchau H, Herberts P, Eisler T, Garellick G, Söderman P.** The Swedish Total Hip Replacement Register. *J Bone Joint Surg [Am]* 2002;84-A(Suppl 2):2-20.
4. **Veitch SW, Whitehouse SL, Howell JR, et al.** The concentric all-polyethylene Exeter acetabular component in primary total hip replacement. *J Bone Joint Surg [Br]* 2010;92-B:1351-1355.
5. **López-López JA, Humphriss RL, Beswick AD, et al.** Choice of implant combinations in total hip replacement: systematic review and network meta-analysis. *BMJ* 2017;359:j4651.
6. **Charnley J.** The long-term results of low-friction arthroplasty of the hip performed as a primary intervention. *J Bone Joint Surg [Br]* 1972;54-B:61-76.
7. **Callaghan JJ, Albright JC, Goetz DD, Olejniczak JP, Johnston RC.** Charnley total hip arthroplasty with cement. Minimum twenty-five-year follow-up. *J Bone Joint Surg [Am]* 2000;82-A:487-497.
8. **Atrey A, Ward SE, Khoshbin A, et al.** Ten-year follow-up study of three alternative bearing surfaces used in total hip arthroplasty in young patients: a prospective randomised controlled trial. *Bone Joint J* 2017;99-B:1590-1595.
9. **Devane PA, Horne JG, Ashmore A, et al.** Highly cross-linked polyethylene reduces wear and revision rates in total hip arthroplasty: a 10-year double-blinded randomized controlled trial. *J Bone Joint Surg [Am]* 2017;99-A:1703-1714.
10. **Jameson SS, Lees D, James P, et al.** Lower rates of dislocation with increased femoral head size after primary total hip replacement: a five-year analysis of NHS patients in England. *J Bone Joint Surg [Br]* 2011;93-B:876-880.
11. **Zijlstra WP, De Hartog B, Van Steenbergen LN, Scheurs BW, Nelissen RGHH.** Effect of femoral head size and surgical approach on risk of revision for dislocation after total hip arthroplasty. *Acta Orthop* 2017;88:395-401.
12. **Biedermann R, Krismer M, Stöckl B, et al.** Accuracy of EBRA-FCA in the measurement of migration of femoral components of total hip replacement. Einzel-Bild-Röntgen-Analyse-femoral component analysis. *J Bone Joint Surg [Br]* 1999;81-B:266-272.
13. **Gruen TA, McNeice GM, Amstutz HC.** "Modes of failure" of cemented stem-type femoral components: a radiographic analysis of loosening. *Clin Orthop Relat Res* 1979;141:17-27.
14. **DeLee JG, Charnley J.** Radiological demarcation of cemented sockets in total hip replacement. *Clin Orthop Relat Res* 1976;121:20-32.
15. **Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW.** Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 1988;15:1833-1840.
16. **Singh J, Sloan JA, Johanson NA.** Challenges with health-related quality of life assessment in arthroplasty patients: problems and solutions. *J Am Acad Orthop Surg* 2010;18:72-82.
17. **Harris WH.** Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation. *J Bone Joint Surg [Am]* 1969;51-A:737-755.
18. **Nilsdotter AK, Lohmander LS, Klässbo M, Roos EM.** Hip disability and osteoarthritis outcome score (HOOS)—validity and responsiveness in total hip replacement. *BMC Musculoskelet Disord* 2003;4:10.
19. **Herdman M, Gudex C, Lloyd A, et al.** Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). *Qual Life Res* 2011;20:1727-1736.
20. **Ware JE Jr, Sherbourne CD.** The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care* 1992;30:473-483.
21. **Mahomed N, Gandhi R, Daltroy L, Katz JN.** The self-administered patient satisfaction scale for primary hip and knee arthroplasty. *Arthritis (Egypt)* 2011;2011:591253.
22. **Saleh KJ, Mulhall KJ, Bershadsky B, et al.** Development and validation of a lower-extremity activity scale. Use for patients treated with revision total knee arthroplasty. *J Bone Joint Surg [Am]* 2005;87-A:1985-1994.
23. **Podsiadlo D, Richardson S.** The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991;39:142-148.
24. **Hart TL, Ainsworth BE, Tudor-Locke C.** Objective and subjective measures of sedentary behavior and physical activity. *Med Sci Sports Exerc* 2011;43:449-456.
25. **Schütz U, Decking J, Decking R, Puhl W.** Assessment of femoral component migration in total hip arthroplasty: digital measurements compared to RSA. *Acta Orthop Belg* 2005;71:65-75.
26. **Bayliss LE, Culliford D, Monk AP, et al.** The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study. *Lancet* 2017;389:1424-1430.
27. **Murray DW, Gulati A, Gill HS.** Ten-year RSA-measured migration of the Exeter femoral stem. *Bone Joint J* 2013;95-B:605-608.
28. **Flatøy B, Röhrl SM, Rydinge J, et al.** Triple taper stem design shows promising fixation and bone remodelling characteristics: radiostereometric analysis in a randomised controlled trial. *Bone Joint J* 2015;97-B:755-761.
29. **Crowninshield RD, Jennings JD, Laurent ML, Maloney WJ.** Cemented femoral component surface finish mechanics. *Clin Orthop Relat Res* 1998;355:90-102.
30. **Siepen W, Zwicky L, Stoffel KK, Ilchmann T, Clauss M.** Prospective two-year subsidence analysis of 100 cemented polished straight stems - a short-term clinical and radiological observation. *BMC Musculoskelet Disord* 2016;17:395.
31. **de Vries LM, van der Weegen W, Pilot P, et al.** The predictive value of radiostereometric analysis for stem survival in total hip arthroplasty. A systematic review. *Hip Int* 2014;24:215-222.
32. **Morita D, Iwase T, Ito T.** Bone restoration with cemented Exeter universal stem - three-years longitudinal DEXA study in 165 hips for femur. *J Orthop Sci* 2016;21: 336-341.
33. **Hofstede SN, Gademan MG, Vliet Vlieland TP, Nelissen RG, Marang-van de Mheen PJ.** Preoperative predictors for outcomes after total hip replacement in patients with osteoarthritis: a systematic review. *BMC Musculoskelet Disord* 2016;17:212.
34. **Judge A, Arden NK, Batra RN, et al.** The association of patient characteristics and surgical variables on symptoms of pain and function over 5 years following primary hip-replacement surgery: a prospective cohort study. *BMJ Open* 2013;3:e002453.
35. **Clement ND, MacDonald D, Howie CR, Biant LC.** The outcome of primary total hip and knee arthroplasty in patients aged 80 years or more. *J Bone Joint Surg [Br]* 2011;93-B:1265-1270.
36. **Cushnaghan J, Coggon D, Reading I, et al.** Long-term outcome following total hip arthroplasty: a controlled longitudinal study. *Arthritis Rheum* 2007;57:1375-1380.
37. **Jeldi AJ, Deakin AH, Allen DJ, et al.** Total hip arthroplasty improves pain and function but not physical activity. *J Arthroplasty* 2017;32:2191-2198.
38. **Lin BA, Thomas P, Spiezia F, Loppini M, Maffulli N.** Changes in daily physical activity before and after total hip arthroplasty. A pilot study using accelerometry. *Surgeon* 2013;11:87-91.
39. **Gandhi R, Tsvetkov D, Davey JR, Syed KA, Mahomed NN.** Relationship between self-reported and performance-based tests in a hip and knee joint replacement population. *Clin Rheumatol* 2009;28:253-257.

Author contributions
- N. D. Clement: Analyzed the data, Wrote the manuscript.
- M. Bardgett: Study co-ordinator, Analyzed the data.
- K. Merrie: Study co-ordinator, Analyzed the data, Reported on clinical governance and safety.
- S. Furtado: Enrolled the patients, Collected the data, activPAL analysis, Wrote the manuscript.
- R. Bowman: Collected the data, EBRA analysis.
- D. J. Langton: Collected the data, BMD analysis.
- D. J. Deehan: Wrote the manuscript.
- J. Holland: Created the concept, Designed the study, Enrolled the patients, Wrote the manuscript.

Funding statement
- Although none of the authors has received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this article, benefits have been or will be received but will be directed solely to a research fund, foundation, educational institution, or other non- profit organization with which one or more of the authors are associated.

Conflict of interest statement

- All authors report an institutional grant and payment for writing or reviewing the manuscript (paid to Freeman Hospital) from Stryker.

Acknowledgements

- The authors would like to acknowledge the contribution of Mr Craig Gerrand, Mr David Weir, Mr Munawar Hashmi, Mr Nigel Brewster, Professor McCaskie, and Mr Andrew Gray for including their patients within this cohort study.

Ethical review statement

- Ethical approval was obtained for this study (REC Ref: 12/NE/0153) and the project was registered with the Research and Development Department (Ref: 6105) and was conducted in accordance with the Declaration of Helsinki and the guidelines for good clinical practice.