Aims
The aim of this study was to compare early functional and health related quality of life outcomes (HRQoL) in patients who have undergone total hip arthroplasty (THA) using a bone conserving short stem femoral component and those in whom a conventional length uncemented component was used. Outcome was assessed using a validated performance based outcome instrument as well as patient reported outcome measures (PROMs).

Patients and Methods
We prospectively analysed 33 patients whose THA involved a contemporary proximally porous coated tapered short stem femoral component and 53 patients with a standard conventional femoral component, at a minimum follow-up of two years. The mean follow-up was 31.4 months (24 to 39). Patients with poor proximal femoral bone quality were excluded. The mean age of the patients was 66.6 years (59 to 77) and the mean body mass index was 30.2 kg/m² (24.1 to 41.0). Outcome was assessed using the Oxford Hip Score (OHS) and the University College Hospital (UCH) hip score which is a validated performance based instrument. HRQoL was assessed using the EuroQol 5D (EQ-5D).

Results
There were no major peri-operative complications. There was no difference in the mean post-operative OHS, EQ-5D or function subscale of the UCH hip scores between the two groups. The mean pre-operative OHS and EQ-5D scores improved significantly (all p < 0.001). The mean functional component of the UCH hip score at final follow-up was 42.5 and 40.6 in the short stem and conventional stem groups, respectively. There was no statistically significant difference between the groups (p = 0.42). A total of seven patients (21.2%) in the short stem group and nine (16.98%) in the conventional group achieved a ceiling effect using the OHS; none did using the function subscale of the UCH hip score.

Conclusion
The proximally porous coated tapered short stem femoral component achieves comparable short-term functional outcomes when compared with a conventional longer stem uncemented femoral component when THA is undertaken in patients with good bone quality.

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Our study cohort (short stem group), consisted of a consecutive series of 33 patients who underwent 33 uncemented THAs between 2013 and 2014 using the Taperloc Microplasty (Biomet, Warsaw, Indiana) femoral component and a Regenerex Ringloc + acetabular shell (Biomet). A control group consisted of 53 patients who underwent 53 THAs using a conventional length Synergy femoral component with a R3 acetabular shell (Smith & Nephew, Memphis, Tennessee). The operations were undertaken by the senior author (FSH). The demographics of the patients in both groups are shown in Table I.

The Taperloc component (Biomet) which has a long history of clinical success has a proximally porous coated flatted taper wedge design allowing proximal fixation and bone loading.\textsuperscript{22,23} The Taperloc Microplasty is an evolution of this design retaining the same principles of metaphyseal bone loading with a hydroxyapatite enhanced proximal porous coating. It is 35 mm shorter than the standard Taperloc component thus preserving more bone stock at revision surgery and allowing minimally invasive approaches.\textsuperscript{24}

The standard length uncemented Synergy component (Smith & Nephew) which has a proximal to distal taper design with a proximal porous coating also has proven long-term clinical success.\textsuperscript{25,26} It has been used successfully in our institution for more than ten years. Both are made from a titanium alloy with a 12/14 taper neck in high and standard offset options.

A standard posterior approach with the patient in a lateral decubitus position was used in all procedures. A standardised protocol of intravenous antibiotic prophylaxis involved cefuroxime, (1.5 g at induction followed by three post-operative 750 mg infusions), and tranexamic acid (1 g intravenously at induction) was used. A vitamin E enhanced, highly crosslinked polyethylene (HXLPE) liner accommodating a 32 mm/36 mm ceramic head was used for patients in the short stem group. A HXLPE liner with a 32 mm/36 mm Oxinium (Smith & Nephew) head was used for those in the conventional stem group. Routine post-

### Table I. Demographic data for both groups

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Short stem group</th>
<th>Conventional stem group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (range)</td>
<td>66.8 (59 to 73)</td>
<td>66.4 (60 to 77)</td>
<td>0.58</td>
</tr>
<tr>
<td>Gender (%)</td>
<td></td>
<td></td>
<td>0.64</td>
</tr>
<tr>
<td>Male</td>
<td>12 (36.4)</td>
<td>22 (58.5)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>21 (63.6)</td>
<td>31 (41.5)</td>
<td></td>
</tr>
<tr>
<td>Body mass index (kg/m^2), mean (range)</td>
<td>30.1 (24.1 to 41.0)</td>
<td>30.3 (26.4 to 39.2)</td>
<td>0.74</td>
</tr>
<tr>
<td>ASA Grade (%)</td>
<td></td>
<td></td>
<td>0.84</td>
</tr>
<tr>
<td>I</td>
<td>18 (54.6)</td>
<td>29 (54.7)</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>14 (42.4)</td>
<td>21 (39.6)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>1 (3.0)</td>
<td>3 (5.7)</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Calcar: canal ratio, mean (range)</td>
<td>0.39 (0.26 to 0.50)</td>
<td>0.44 (0. to 0.57)</td>
<td>0.27</td>
</tr>
</tbody>
</table>

ASA, American Society of Anesthesiologists

Patients and Methods

The inclusion criteria for this comparative case series study were patients aged < 80 years, with osteoarthritis requiring a THA who were in good health and had good bone stock on plain radiographs. Patients with Dorr C\textsuperscript{20} type femurs were excluded due to poor bone quality and proximal femoral morphology. We preferred to use a cemented taper slip component for these patients.\textsuperscript{21}

A standard posterior approach with the patient in a lateral decubitus position was used in all procedures. A standardised protocol of intravenous antibiotic prophylaxis involved cefuroxime, (1.5 g at induction followed by three post-operative 750 mg infusions), and tranexamic acid (1 g intravenously at induction) was used. A vitamin E enhanced, highly crosslinked polyethylene (HXLPE) liner accommodating a 32 mm/36 mm ceramic head was used for patients in the short stem group. A HXLPE liner with a 32 mm/36 mm Oxinium (Smith & Nephew) head was used for those in the conventional stem group. Routine post-
operative thromboprophylaxis involved 5000 units of dalteparin (Fragmin, Pfizer, Walton Oaks, United Kingdom) and anti-embolism stockings while in hospital, and oral rivaroxaban (Xarelto, Bayer, United Kingdom) thereafter for a total of 35 days. Routine mobilisation fully weight-bearing started, with a physiotherapist, who was blinded to the type of stem which had been used, on the first post-operative day. The patients were discharged when they were able to walk and climb stairs, with or without walking aids, independently. They were reviewed at six weeks and six months post-operatively and annually thereafter with standardised supine anteroposterior radiographs of the pelvis with the feet in neutral rotation. Outcome was assessed using the Oxford Hip Score (OHS), and HRQoL using the EuroQol 5D questionnaire on a five point Likert scale (EQ-5D). These data were collected pre-operatively and at each post-operative review by a research physiotherapist (JT). The calculated utility scores for EQ-5D were based on United Kingdom population reference data. The UCH hip score was recorded by one of the authors (FH) at the most recent follow-up. This score assesses function (UCH-F; best score 25 and worst 100) by the measurement of performance in five tasks and the difficulty and pain (UCH-D and UCH-P; best score ten and worst 100) in performing these tasks.

The radiographs were retrospectively analysed on the AGFA Impax 6 picture archiving and communications system (Agfa, Mortsel, Belgium). Radiographic assessment was undertaken by a clinical fellow (AV) who was blinded to the outcome scores in both groups. The position of the components at six weeks post-operatively and at two-year follow-up was recorded. This included the inclination of the acetabular component referenced to the interteardrop line and anteversion as described by Lewinnek et al and more recently, validated by Lu et al. The valgus/varus alignment of the stem was recorded using the method described by Khalily and Lester. The outlines of the components from the templating software were superimposed on the post-operative images to allow the determination of the long axis of the femoral component which was subtended against the axis of the endosteal border of the medial cortex as seen in Figure 1. The early post-operative radiographs from the first ten patients of both groups were analysed by two observers (AV and FH) to assess inter-observer reliability using the single measures, two way mixed effects intraclass correlation coefficient. Subsidence was evaluated from the immediate post-operative radiographs and those at final follow-up, as a vertical movement of the femoral component, characterised by a radiolucent space at the most proximal aspect of the bone-implant interface. Magnification was adjusted based on the diameter of the femoral head component. Subsidence of ≥ 2 mm was considered to be significant. Osteolysis and loosening was defined as a lucency of > 2 mm with a sclerotic margin at the bone-implant interface at different Gruen zones around the femoral component at final follow-up. The morphology of the proximal femur was assessed on the pre-operative radiographs as the calcar:canal ratio as described by Dorr et al. The presence of osteolysis and loosening at the bone-acetabular interface was also documented.

The study had institutional approval and all patients gave informed consent. Statistical analysis. This was performed using SPSS version 20 (IBM, Armonk, New York). Descriptive statistics were expressed as percentages, means, and ranges. The Wilcoxon signed-rank test was used to compare continuous pre- and post-operative data and the Mann-Whitney U test was used to compare the two groups. Categorical data were compared using the chi-squared test. Based on the original development and validation study of the UCH hip score, with its UCH-F subscale as the primary endpoint we assumed a minimal clinically important difference of seven points. A p-value of < 0.05 was considered statistically significant. A non-inferiority trial sample size of a minimum of 78 patients would be required to achieve a power of 0.8 at an α of 0.05 based on previous results.

Results
The mean follow-up was 31.4 months (24 to 39). There were no intra-operative fractures. The size of the femoral component which was used was within one size of the template in all patients. There were no early post-operative complications such as deep vein thrombosis, pulmonary embolism or infection in the short stem group. A single patient in the short stem group had a superficial haematoma; the thromboprophylaxis was stopped and no further treatment was required.

The outcome scores are shown in Table II. There was a significant improvement in the mean OHS and EQ-5D scores in both groups with no significant difference between the two groups at final follow-up. There was no
There was a 21.2% ceiling effect in the assessment of function using the OHS in the short stem group and 16.98% in the conventional stem group. In contrast, there was no ceiling effect when using the UCH-F score.

The inter-observer reliability coefficient was 0.90, 0.86 and 0.73 for radiographic assessment of acetabular inclination, acetabular version and the valgus/varus alignment of the femoral component, respectively. The radiographic results are shown in Table III. There was no significant difference in the mean inclination or anteversion of the acetabular component between the two groups. No radiolucent lines were seen around the acetabular component in any patient. There was a statistically significant difference in the mean femoral varus angle at six weeks and two-year follow-up between the two groups. There was however no difference in the amount of femoral component migration during the follow-up interval between the two groups.

There was no correlation between the calcar:canal ratio and the alignment of the femoral component in either group (short stem group: Pearson’s r = -0.34, p = 0.053; conventional stem group: Pearson’s r = -0.063, p = 0.65).

One patient in the short stem group had subsidence of the femoral component of 1.5 mm. The subsidence was noticed between six weeks and six months. The patient was asymptomatic and the stem showed subsequent signs of stabilisation and osseointegration at two year follow-up. No patient in either group had evidence of osteolysis or lucency in any Gruen zone. No patient in either group had an infection or required revision. One patient in the short stem group developed Brooker class 1 heterotopic ossification (HO) at final follow-up. The intra-operative procedure for this patient was unremarkable. There were no identifiable pre-operative risk factors of HO apart from male gender.

**Table II.** Mean (range) pre- and post-operative functional scores for both groups

<table>
<thead>
<tr>
<th>Score</th>
<th>Short stem group</th>
<th>Conventional stem group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-operative OHS</td>
<td>13.5 (2 to 37)</td>
<td>13.6 (2 to 34.3)</td>
<td>0.64</td>
</tr>
<tr>
<td>Post-operative OHS</td>
<td>41.5 (32 to 48)</td>
<td>40.1 (24 to 48)</td>
<td>0.78</td>
</tr>
<tr>
<td>Pre-operative EQ-SD</td>
<td>0.275 (0.111 to 0.639)</td>
<td>0.287 (0.092 to 0.767)</td>
<td>0.95</td>
</tr>
<tr>
<td>Post-operative EQ-SD</td>
<td>0.754 (0.531 to 1.00)</td>
<td>0.746 (0.531 to 1.00)</td>
<td>0.91</td>
</tr>
<tr>
<td>UCH-F</td>
<td>42.5 (30 to 55)</td>
<td>40.6 (30 to 55)</td>
<td>0.42</td>
</tr>
<tr>
<td>UCH-D</td>
<td>24 (10 to 58)</td>
<td>20.9 (10 to 58)</td>
<td>0.69</td>
</tr>
<tr>
<td>UCH-P</td>
<td>12.5 (10 to 34)</td>
<td>11.5 (10 to 32)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

OHS, Oxford Hip Score; EQ-SD, EuroQol 5D; UCH, University College Hospital; UCH-F, UCH function; UCH-D, UCH difficulty; UCH-P, UCH pain

**Table III.** Radiographic results of the position of the components for both groups

<table>
<thead>
<tr>
<th>Mean angle (range)</th>
<th>Short stem group</th>
<th>Conventional stem group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetabular component</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inclination</td>
<td>38.5° (31° to 46.7°)</td>
<td>37.9° (34.2° to 44.7°)</td>
<td>0.17</td>
</tr>
<tr>
<td>Anteversion</td>
<td>21.1° (9.8° to 27.4°)</td>
<td>17.7° (6.9° to 25.8°)</td>
<td>0.29</td>
</tr>
<tr>
<td>Femoral component varus angle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 wks</td>
<td>2.1° (0.2° to 3.8°)</td>
<td>1.4° (-1.3° to 4.3°)</td>
<td>0.03</td>
</tr>
<tr>
<td>2 yrs</td>
<td>2.9° (1.1° to 4.0°)</td>
<td>2.3° (0.1° to 5.0°)</td>
<td>0.03</td>
</tr>
<tr>
<td>Varus migration</td>
<td>0.90° (0.8° to 3.5°)</td>
<td>0.88° (0.0° to 4.9°)</td>
<td>0.83</td>
</tr>
</tbody>
</table>

**Discussion**

We found a significant early improvement in both patient reported and performed functional outcome assessment with improvement in HRQoL in patients who underwent THA using both short stem and conventional uncemented femoral components. There was no difference between the two groups. Radiographically there was no evidence of progressive subsidence, lucency or significant migration of the femoral components.

The Taperloc Microplasty stem has a tapered design with proximal porous coating allowing for metaphyseal fixation. It is similar to the conventional porous coated taper wedge design but with a shorter length allowing only minimal contact at the diaphysis. There is thus minimal stress shielding proximally allowing for more physiological bone loading.12

There was significant improvement in PROMs using the OHS in both groups. At a mean follow-up of 31.4 months, the mean OHS score had improved to 41.5 and 40.1 in the short stem and conventional stem groups, respectively. This is in keeping with other studies of outcomes when using uncemented femoral stems.36-38
mid-term outcomes of ceramic-on-ceramic THA using three different types of conventional length uncemented femoral components showed similar improvements with a mean post-operative OHS score of 40.89 at a mean follow-up of 59 months. Similarly, a previous study assessing function at a mean follow-up of 1.7 years, in 65 THAs using a laterally flared short stem femoral component (Proxima Hip, Depuy, Leeds, United Kingdom), showed a mean improvement in OHS score to 47.5. In that study, the patients had a comparatively better mean pre-operative OHS score of 18.37. Our results are also comparable with those of the National Joint Registry which has reported a median improvement in the OHS score of 41 from 18 pre-operatively in > 90,000 THAs of all designs at six-month follow-up.38 There was no difference in the mean post-operative OHS scores between the two groups in our study. Furthermore, the similarity of the mean post-operative OHS scores in the short stem group compared with that reported for conventional length uncemented components suggests that patient perceived function is no different between the short and longer designs of stem. This is further supported by the results of studies comparing these two lengths of stem which have shown no difference in PROM-based functional outcomes between the two.15,39

Patient performed function as measured using the UCH hip score showed satisfactory outcomes at final follow-up in both groups. Although we did not have the benefit of pre-operative scores, these results compare favourably with that of a previous study of conventional THA and resurfacing arthroplasty in patients aged < 55 years with an improvement in the mean UCH-F score to 63.0 from 78.5.35 Interestingly, in the same study, the mean post-operative UCH-F score for resurfacing arthroplasty was better than that of our cohort in this study at 30.3 improving from 79.1.

We failed to show a difference in performance based functional outcome scores between the two groups at final follow-up despite our instrument’s more favourable discriminative ability in assessing high end function compared with more conventional PROMs. Our findings are in keeping with those of Brevadt et al40 who in a three arm high function gait study did not find any functional advantage of short stems over long stems in high speed walking and gait symmetry. They did, however, show a functional advantage of the head and neck preserving resurfacing component compared with stemmed components.

Our patients showed a 21.2% and 16.98% ceiling effect when using the OHS in younger patients (between 50 and 59 years) who have undergone THA.42 This study further showed a 19.9% ceiling effect for the functional component of the OHS in all age groups. It has therefore been suggested that such ceiling effects may result in false negative errors of outcome assessment in comparative studies of arthroplasty particularly in younger patients. The complementary use of more robust instruments such as the UCH hip or knee score43 in addition to PROMs has therefore been recommended in comparative arthroplasty research.18,44 In our patients, using this score allowed the assessment of functionally high achieving patients without reaching a ceiling effect.

The concurrent improvement in the EQ-5D score in these patients is also in keeping with data from national registries of outcomes of THA. The mean EQ-5D score in > 30,000 patients from the Swedish Hip Arthroplasty Register showed an improvement from 0.41 pre-operatively to 0.78 post-operatively at one year follow-up.45 There was no difference with respect to EQ-5D scores between the two groups in our study. This is perhaps to be expected given that there was no difference in the post-operative OHS scores between the groups. It is well established that domain specific PROMs are more responsive to change than generic HRQoL instruments.46-49

No patients had radiographic evidence of loosening or osteolysis. This is also to be expected given that the Taperloc Microplasty stem has the same design philosophy of proximal metaphysial loading as the original Taperloc component24 and many other longer conventional taper wedge uncemented femoral components. They have all been shown to have satisfactory radiographic and long-term outcomes.5,22,23 The opponents of such short stem designs may, however, argue that improved proximal bone loading with a shortened length of stem may come at the cost of reduced primary stability leading to migration when compared with longer uncemented components, and a subsequent negative impact on survivorship.6 Our study showed a statistically significant difference with respect to increased varus positioning of the component in the short stem group when compared with the conventional stem; however, there was no difference in varus migration over a two-year time period in either group. In contrast, a previous randomised controlled trial (RCT) comparing migration of the femoral component over time using radiostereometric analysis (RSA) showed a statistically significant change in varus/valgus tilt between short and long stem femoral components two years after THA.50 The findings are consistent with those of other studies which have similarly shown evidence of early varus migration when using a short stem in THA.51 However, such patterns of migration of uncemented femoral components are of questionable clinical significance with previous authors reporting no impact on the clinical outcome.30,52,53 Long-term studies are required to assess the effect of migration of short stems on survivorship.
Our study is limited by its small sample size and the short follow-up. These patients continue to be followed up. We have, however, evaluated a single surgeon series of patients undergoing THA using a contemporary design of short stem with a control group of patients who have undergone THA by the same surgeon using a well-known femoral component with established clinical success. This perhaps aids in reducing the heterogeneity of our patients. Furthermore, our comprehensive assessment of function includes the use of a performance-based instrument which complements and minimises the problems associated with use of function assessed using PROMs. Although our study is not a RCT, it has paved the way for an ongoing RCT comparing the use of a short stem femoral component with a conventional component. Given that we excluded Dorr type C femurs from our study, it is possible that we may have avoided the findings of other studies of subsidence in uncemented THA. Our radiographic assessment may not have accounted for possible errors owing to the position of the patient and tilt in the assessment of the varus angle of the stem. This will be further addressed in our ongoing RCT with RSA analysis.

In conclusion, we found that the efficacy of a proximally porous coated bone conserving short stem femoral component compared favourably with that of a conventional standard length uncemented component both in terms of actual and patient perceived functional outcomes. While the early radiological findings are also reassuring, long-term follow-up is needed to assess the impact of the alignment and migration of a short stem on survivorship.

Take home message:
- There is no difference in functional outcome in patients who have undergone total hip arthroplasty using short stem femoral components, compared with those with conventional length femoral components.

Author contributions:
F. Hossain: Contributed to the data collection, analysis and interpretation, Write up of the manuscript.
S. Konan: Contributed to the conception and design of the project, Data collection, Drafting of the manuscript.
A. Volpin: Contributed to data collection and analysis.
F. S. Haddad: Contributed to the design and conception of the project, Data collection, analysis and interpretation, Final approval of the manuscript.

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References