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## ■ HIP

# A multicentre comparative analysis of fixation versus revision surgery for periprosthetic femoral fractures following total hip arthroplasty with a cemented polished taper-slip femoral component

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### Aims

The aim of this study was to compare open reduction and internal fixation (ORIF) with revision surgery for the surgical management of Unified Classification System (UCS) type B periprosthetic femoral fractures around cemented polished taper-slip femoral components following primary total hip arthroplasty (THA).

### Methods

Data were collected for patients admitted to five UK centres. The primary outcome measure was the two-year reoperation rate. Secondary outcomes were time to surgery, transfusion requirements, critical care requirements, length of stay, two-year local complication rates, six-month systemic complication rates, and mortality rates. Comparisons were made by the form of treatment (ORIF vs revision) and UCS type (B1 vs B2/B3). Kaplan-Meier survival analysis was performed with two-year reoperation for any reason as the endpoint.

### Results

A total of 317 periprosthetic fractures (in 317 patients) with a median follow-up of 3.6 years (interquartile range (IQR) 2.0 to 5.4) were included. The fractures were type B1 in 133 (42.0%), B2 in 170 (53.6%), and B3 in 14 patients (4.4%). ORIF was performed in 167 (52.7%) and revision in 150 patients (47.3%). The two-year reoperation rate (15.3% vs 7.2%;  $p = 0.021$ ), time to surgery (4.0 days (IQR 2.0 to 7.0) vs 2.0 days (IQR 1.0 to 4.0);  $p < 0.001$ ), transfusion requirements (55 patients (36.7%) vs 42 patients (25.1%);  $p = 0.026$ ), critical care requirements (36 patients (24.0%) vs seven patients (4.2%);  $p < 0.001$ ) and two-year local complication rates (26.7% vs 9.0%;  $p < 0.001$ ) were significantly higher in the revision group. The two-year rate of survival was significantly higher for ORIF (91.9% (standard error (SE) 0.023%) vs 83.9% (SE 0.031%);  $p = 0.032$ ) compared with revision. For B1 fractures, the two-year reoperation rate was significantly higher for revision compared with ORIF (29.4% vs 6.0%;  $p = 0.002$ ) but this was similar for B2 and B3 fractures (9.8% vs 13.5%;  $p = 0.341$ ). The most common indication for reoperation after revision was dislocation (12 patients; 8.0%).

### Conclusion

Revision surgery has higher reoperation rates, longer surgical waiting times, higher transfusion requirements, and higher critical care requirements than ORIF in the management of periprosthetic fractures around polished taper-slip femoral components after THA. ORIF is a safe option providing anatomical reconstruction is achievable.

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## Introduction

Cemented total hip arthroplasty (THA) provides excellent long-term outcomes and is cost-effective.<sup>1–4</sup> Polished taper-slip (PTS) femoral components are the most common cemented femoral components which are used in the UK, having largely replaced traditional composite-beam (CB) components.<sup>5</sup> Due to their clinical and cost-effectiveness, a Best Practice Tariff was introduced to NHS providers to encourage their use in patients aged > 70 years.<sup>5,6</sup>

Despite lower rates of aseptic loosening, PTS femoral components have a higher risk of periprosthetic femoral fracture compared with CB femoral components.<sup>7–13</sup> The incidence of periprosthetic fractures is increasing by 13% each year and is a common indication for revision THA.<sup>5,14</sup> Periprosthetic fracture is a serious complication usually requiring surgical management, which is associated with high complication rates and costs.<sup>15,16</sup> Surgical treatment is guided by the Unified Classification System (UCS) and, for type B fractures occurring around the femoral component, involves open reduction and internal fixation (ORIF) for fractures around well-fixed components (B1) or revision ( $\pm$  ORIF) for fractures around loose components (B2) or in the presence of severe bone loss (B3).<sup>17</sup> While this is well-accepted for fractures around CB components, there is considerable variation in practice when treating fractures around PTS components.<sup>18</sup> This disparity is due to differences in their methods of fixation and the subsequent effect on their stability at the time of fracture. CB components rely on a mechanical interlock at both the component-cement and cement-bone interfaces. PTS components allow controlled subsidence at the component-cement interface but require a well-interdigitated cement-bone interface. Many surgeons offer revision surgery for all type B periprosthetic fractures around PTS components, while some favour ORIF providing that the cement-bone interface is maintained and that anatomical reconstruction of the bone and cement mantle is achievable.

The clinical evidence for operatively managing type B periprosthetic fractures around PTS components is sparse and there are only single-centre studies reporting clinical outcomes, which limits the generalizability of the conclusions. Smitham et al<sup>19</sup> reported an 11.4% reoperation rate following ORIF in a series of 44 periprosthetic fractures. Maggs et al<sup>20</sup> reviewed 87 periprosthetic fractures treated with revision and described reoperation in 20.7%. Powell-Bowns et al<sup>21</sup> reviewed 152 periprosthetic fractures and reported rates of reoperation of 11% with ORIF and 55% with revision. However, the optimal surgical treatment remains unknown.

The aim of this study was to compare clinical outcomes of ORIF and revision in a multicentre series of type B periprosthetic fractures occurring around a PTS femoral component following primary THA.

## Methods

NHS Health Research Authority ethical approval was obtained for this multicentre observational cohort study (REC 21/PR/0856). Patients with a UCS type B periprosthetic fracture around a primary THA with a PTS femoral component consecutively admitted to each of five UK centres between 8 March

2007 and 14 May 2020, who were treated surgically, were included. Exclusion criteria were intraoperative fractures, fractures around a hemiarthroplasty, a hip resurfacing, a revision THA, or a trauma implant and interprosthetic fractures.

Data were collected from electronic patient records and radiographs using local picture archiving and communication system (PACS) software. Anonymized data were recorded for the characteristics of the patients, details of the primary THA, the periprosthetic fracture and its management. Demographic data included sex, age at the time of fracture, pre- and postoperative residential status (own home, supported living, residential home or nursing home), BMI, American Society of Anesthesiologists (ASA) grade,<sup>22</sup> and Charlson Comorbidity Index (CCI).<sup>23</sup> Details of the primary THA included the indication, the fixation of the acetabular component (cemented or cementless), and its type (standard articulation, dual-mobility, or constrained). The details of the periprosthetic fracture included the laterality, mechanism of injury (low energy or high energy), UCS type (B1, B2, or B3), multifragmentary fracture pattern, associated wear or loosening of the acetabular component, whether the femoral cement was well-fixed to bone and if the femoral component was still held in its centralizer. For consistency, a B1 fracture was defined by a well-fixed femoral component, a B2 fracture by radiolucency at either the component-cement interface or the cement-bone interface, and a B3 fracture by severe comminution and/or bone loss. Details of the surgical treatment included whether it involved ORIF or a revision, the type of ORIF (cerclage fixation only, plate only, or combined plate and cerclage), use of a periprosthetic fracture-specific locking plate, use of fluoroscopy, the type of the revision femoral component (long cementless modular, long cementless non-modular, long, standard length or short cemented component, or a proximal femoral replacement), details of the revision acetabular component (standard articulation, dual-mobility, constrained, or not revised), and the use and type of femoral bone graft. ORIF was defined by the use of any fixation device placed internally without removal of the components of the THA, their exchange or modification. Revision was defined by removal, exchange or modification of any component of the THA with or without the use of an additional fixation device. The choice of surgery was determined by the operating surgeon, but ORIF was only considered if stable anatomical reconstruction of the femur and cement mantle could be achieved or if the patient was too frail to undergo revision.

The primary outcome measure was the two-year reoperation rate. Secondary outcomes were time to surgery (days), 72-hour blood transfusion requirements, postoperative critical care (in a high dependency or intensive care unit) requirements, length of stay (LOS) in days, return to usual residence, the 90-day reoperation rate, the 30-day readmission rate, the two-year local and six-month systemic complication rates, and the 30-day and one-year mortality rates. Final follow-up was determined by the date of the latest clinical or radiological review.

**Statistical analysis.** Analyses were undertaken using SPSS v. 27.0 (IBM, USA). Data were tested for normality using the Shapiro-Wilk test and compared between the ORIF and revision groups. Data were reported as means with 95% confidence intervals (CIs) or medians with interquartile ranges (IQRs) for

**Table I.** Comparison of baseline characteristics between groups (all B fractures).

Variable	ORIF	Revision	p-value
Total, n (%)	167 (52.7)	150 (47.3)	
Female, n (%)	81 (48.5)	62 (41.3)	0.200*
Right sided PFF, n (%)	80 (47.9)	86 (57.3)	0.093*
Median follow-up, yrs (IQR)	3.5 (1.5 to 6.1)	3.9 (2.7 to 4.9)	0.377†
<b>Age at PFF, n (%)</b>			0.859*
< 50 yrs	1 (0.6)	2 (1.3)	
50 to 59 yrs	8 (4.8)	9 (6.0)	
60 to 69 yrs	23 (13.8)	20 (13.3)	
70 to 79 yrs	48 (28.7)	48 (32.0)	
> 80 yrs	87 (52.1)	71 (47.3)	
<b>Preoperative residential status, n (%)</b>			0.002*
Own home	123 (73.7)	135 (90.0)	
Supported living	18 (10.8)	6 (4.0)	
Residential home	12 (7.2)	6 (4.0)	
Nursing home	14 (8.4)	3 (2.0)	
Median BMI, kg/m <sup>2</sup> (IQR)	26 (23 to 31)	27 (24 to 31)	0.423†
<b>ASA grade, n (%)</b>			0.190*
I	8 (4.8)	15 (10.0)	
II	43 (25.7)	52 (34.7)	
III	86 (51.5)	55 (36.7)	
IV	15 (9.0)	8 (5.3)	
Unknown	15 (9.0)	20 (13.3)	
Median CCI (IQR)	5 (4 to 7)	4 (3 to 6)	0.352*
<b>Indication for primary THA, n (%)</b>			0.925*
Osteoarthritis	120 (71.9)	113 (75.3)	
Rheumatoid arthritis	3 (1.8)	2 (1.3)	
Avascular necrosis	2 (1.2)	1 (0.7)	
Hip fracture	11 (6.6)	11 (7.3)	
Failed trauma	5 (3.0)	3 (2.0)	
Tumour	0 (0.0)	1 (0.7)	
Childhood hip disease	2 (1.2)	1 (0.7)	
Unknown	24 (14.4)	18 (12.0)	
<b>Primary acetabular component fixation, n (%)</b>			< 0.001*
Cemented	131 (78.4)	70 (46.7)	
Cementless	36 (21.6)	80 (53.3)	
<b>Primary acetabular component type, n (%)</b>			0.366*
Standard	156 (93.4)	140 (93.3)	
Dual-mobility	9 (5.4)	10 (6.7)	
Constrained	2 (1.2)	0 (0.0)	
<b>Mechanism of injury, n (%)</b>			0.010*
Low-energy	160 (95.8)	132 (88.0)	
High-energy	7 (4.2)	18 (12.0)	
<b>Multifragmentary, n (%)</b>			< 0.001*
No	138 (82.6)	86 (57.3)	
Yes	29 (17.4)	64 (42.7)	
<b>Associated acetabular component wear or loosening, n (%)</b>			0.112*
No	165 (98.8)	144 (96.0)	
Yes	2 (1.2)	6 (4.0)	

Continued

**Table I.** Continued

Variable	ORIF	Revision	p-value
<b>Femoral cement well-fixed to bone, n (%)</b>			< 0.001*
No	18 (10.8)	40 (26.7)	
Yes	149 (89.2)	110 (73.3)	
<b>Femoral component remaining in the centralizer, n (%)</b>			< 0.001*
No	26 (15.6)	52 (34.7)	
Yes	141 (84.4)	98 (65.3)	

\*Chi-squared test.

†Mann-Whitney U test.

ASA, American Society of Anesthesiologists; CCI, Charlson Comorbidity Index; IQR, interquartile range; ORIF, open reduction and internal fixation; PFF, periprosthetic femoral fracture; THA, total hip arthroplasty.

**Table II.** Surgery performed for periprosthetic femoral fractures around polished taper-slip femoral components (all B fractures).

Variable	ORIF	Revision
Total	167 (52.7)	150 (47.3)
<b>ORIF type, n (%)</b>		
Cerclage fixation only	6 (3.6)	N/A
Plate only	21 (12.6)	N/A
Plate and cerclage fixation	140 (83.8)	N/A
<b>ORIF plate type, n (%)</b>		
Conventional plate	111 (68.9)	N/A
PFF-specific locking plate	50 (31.1)	N/A
Intraoperative fluoroscopy for ORIF	70 (41.9)	N/A
<b>Revision femoral component, n (%)</b>		
Long cementless modular	N/A	97 (64.7)
Long cementless non-modular	N/A	3 (2.0)
Cemented femoral component standard	N/A	13 (8.7)
Cemented femoral component short	N/A	2 (1.3)
Cemented femoral component long	N/A	23 (15.3)
Proximal femur arthroplasty	N/A	12 (8.0)
<b>Acetabular component revision, n (%)</b>		
Standard	N/A	10 (6.7)
Dual-mobility	N/A	7 (4.7)
Constrained	N/A	5 (3.3)
Not revised	N/A	128 (85.3)
Use of femoral bone graft, n (%)	2 (1.2)	2 (1.3)
<b>Graft type, n (%)</b>		
Impaction bone grafting	0 (0.0)	2 (1.3)
Cortical strut graft	2 (1.2)	0 (0.0)

N/A, not applicable; ORIF, open reduction and internal fixation; PFF, periprosthetic femoral fracture.

continuous variables and percentages for categorical variables. Descriptive statistics were used to report the characteristics of the patients at baseline. Comparisons between independent continuous variables were performed using the Mann-Whitney U test. Comparisons of independent categorical variables were performed using the chi-squared test but where assumptions for this were not met, Fisher's exact test was used. A comparison of outcomes was performed for the whole cohort followed by a subgroup comparison of outcomes by UCS type (well-fixed (B1) vs loose femoral components (B2 and B3)). Cumulative survival rates (%) with standard error (SE) were assessed using

**Table III.** Comparison of outcomes (open reduction and internal fixation vs revision for all B fractures).

Variable	ORIF	Revision	p-value
Total, n (%)	167 (52.7)	150 (47.3)	
Median time to surgery, days (IQR)	2.0 (1.0 to 4.0)	4.0 (2.0 to 7.0)	< 0.001
Blood transfusion needed in 72 hrs, n (%)	42 (25.1)	55 (36.7)	0.026
Median units of blood transfused (IQR)	2 (2 to 2)	2 (1 to 2)	0.615
<b>Postoperative destination, n (%)</b>			< 0.001
Orthopaedic ward	160 (95.8)	114 (76.0)	
High dependency unit	4 (2.4)	17 (11.3)	
Intensive care unit	3 (1.8)	19 (12.7)	
Median LOS, days (IQR)	17.0 (11.0 to 30.0)	19.0 (13.0 to 25.0)	0.991
Return to usual residence, n (%)	128 (76.6)	122 (81.3)	0.308
Reoperation in 90 days, n (%)	6 (3.6)	11 (7.3)	0.140
Reoperation in 2 yrs, n (%)	12 (7.2)	23 (15.3)	0.021
Median days to first reoperation (IQR)	90.0 (23.0 to 475.0)	105.0 (47.0 to 195.0)	0.889
Median total reoperations, n (IQR)	1 (1 to 2)	1 (1 to 2)	0.861
Readmissions in 30 days, n (%)	7 (4.7)	5 (3.1)	0.561
Median days to readmission (IQR)	11.0 (3.0 to 19.0)	7.0 (2.0 to 12.0)	0.413
Median readmission LOS, days (IQR)	1.0 (1.0 to 7.0)	2.0 (2.0 to 21.0)	0.284
Local complications in 2 yrs, n (%)	15 (9.0)	40 (26.7)	< 0.001
Median days to local complication in 2 yrs (IQR)	68.0 (33.0 to 193.0)	78.0 (27.0 to 169.0)	0.720
Systemic complication in 6 months, n (%)	27 (16.2)	24 (16.0)	0.968
Median days to systemic complication in 6 months (IQR)	14.0 (2.0 to 22.0)	7.5 (6.0 to 24.0)	0.872
<b>Mortality, n (%)</b>			
30 days	8 (4.8)	2 (1.3)	0.073
1 year	30 (18.0)	18 (12.0)	0.139
Median days to death within 1 year (IQR)	97.0 (28.0 to 204.0)	185.0 (50.0 to 313.0)	0.163

IQR, interquartile range; LOS, length of stay; ORIF, open reduction and internal fixation.

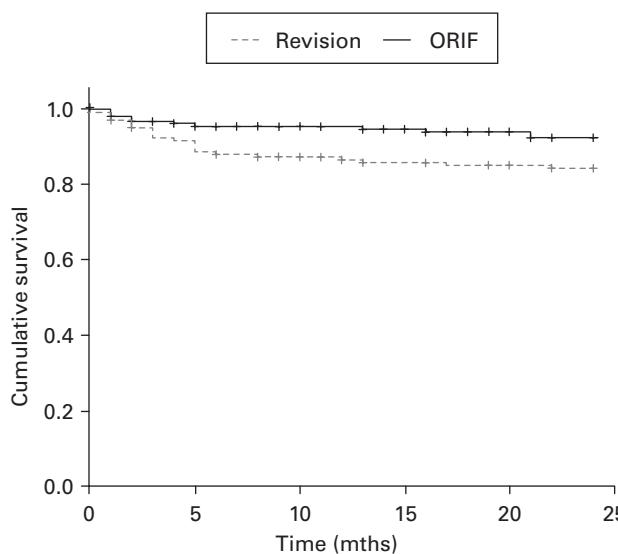


Fig. 1

Kaplan-Meier survival analysis of open reduction and internal fixation (ORIF) versus revision (all type B fractures).

Kaplan-Meier methodology with a two-year reoperation for any reason as the endpoint. Patients who died before the end of the two-year period were censored. Log-rank statistics were used to compare the methods of treatment. Statistical significance was set to  $p < 0.05$ .

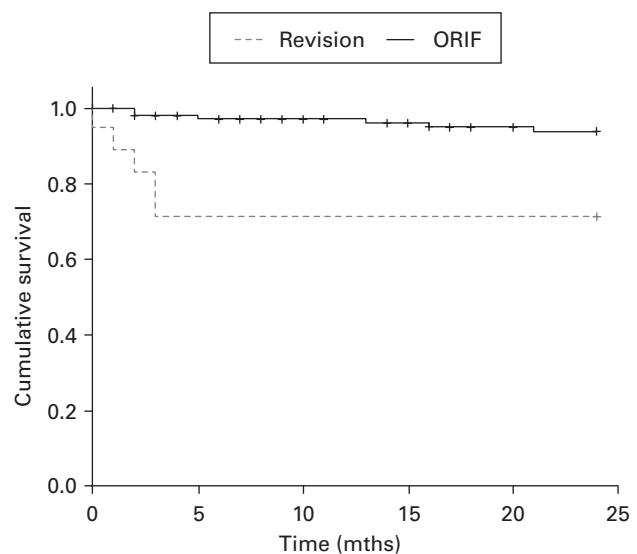


Fig. 2

Kaplan-Meier survival analysis of open reduction and internal fixation (ORIF) versus revision (B1 fractures).

## Results

A total of 317 unilateral periprosthetic fractures around PTS femoral components in 317 patients were included with a median follow-up of 3.6 years (IQR 2.0 to 5.4). All patients were accounted for, with no loss to follow-up. Their median

**Table IV.** Indications for reoperation, readmission, and complications (all B fractures).

Variable	ORIF	Revision
Total	167 (52.7)	150 (47.3)
<b>First reoperation indication, n (%)</b>		
Fixation failure	4 (2.4)	0 (0.0)
Local infection	3 (1.8)	2 (1.3)
Dislocation	1 (0.6)	12 (8.0)
Further PFF	1 (0.6)	3 (2.0)
Femoral component loosening	3 (1.8)	3 (2.0)
Haematoma	0 (0.0)	2 (1.3)
Nonunion	0 (0.0)	1 (0.7)
Total	12 (7.2)	23 (15.3)
<b>First reoperation type, n (%)</b>		
Debridement for infection	3 (1.8)	2 (1.3)
Evacuation of haematoma	0 (0.0)	2 (1.3)
Reduction of dislocated THA	1 (0.6)	8 (5.3)
Revision ORIF	4 (2.4)	0 (0.0)
ORIF of further PFF	1 (0.6)	2 (1.3)
Revision THA (both components)	1 (0.6)	4 (2.7)
Revision THA (femoral component only)	2 (1.2)	4 (2.7)
Revision THA (acetabular component only)	0 (0.0)	1 (0.7)
Total	12 (7.2)	23 (15.3)
<b>Readmissions in 30 days, n (%)</b>		
Sepsis	1 (0.6)	1 (0.7)
Dislocation	0 (0.0)	1 (0.7)
Chest infection	0 (0.0)	1 (0.7)
Further PFF	0 (0.0)	1 (0.7)
Fall	1 (0.6)	0 (0.0)
Loose femoral component	1 (0.6)	0 (0.0)
Local infection	1 (0.6)	0 (0.0)
Wound leak	1 (0.6)	0 (0.0)
Pain	2 (1.2)	0 (0.0)
Seizure	0 (0.0)	1 (0.7)
Total	7 (4.7)	5 (3.1)
<b>Local complication in 2 yrs, n (%)</b>		
Chronic pain related to plate	1 (0.6)	1 (0.7)
Dislocation	1 (0.6)	13 (9.3)
Fixation failure	4 (2.4)	1 (0.7)
Further PFF	2 (1.2)	8 (5.3)
Haematoma	0 (0.0)	2 (1.3)
Heterotopic ossification	0 (0.0)	1 (0.7)
Femoral component loosening	4 (2.4)	5 (3.1)
Local infection	2 (1.2)	2 (1.3)
Intraoperative PFF	0 (0.0)	2 (1.3)
Symptomatic leg length difference	0 (0.0)	1 (0.7)
Nonunion	0 (0.0)	4 (2.7)
Sciatic nerve injury	1 (0.6)	0 (0.0)
Total	15 (9.0)	40 (26.7)

ORIF, open reduction and internal fixation; PFF, periprosthetic femoral fracture; THA, total hip arthroplasty.

age was 79.9 years (IQR 72.0 to 86.0) and 143 (45.1%) were female. Their median BMI was 26.4 kg/m<sup>2</sup> (IQR 23.2 to 30.6), median ASA grade was 3.0 (IQR 2.0 to 3.0), and median CCI was 5.0 (IQR 3.0 to 6.0). A total of 201 fractures involved a fully cemented THA (63.4%) and 116 involved a hybrid THA with a cementless acetabular component (36.6%). There were 166 right-sided fractures (52.4%) and 25 occurred following a high-energy injury (7.9%). The fracture was type B1 in 133 (42.0%), B2 in 170 (53.6%), and B3 in 14 patients (4.4%).

Eight acetabular components (2.5%) were loose or worn and the femoral cement was well-fixed in 259 patients (81.7%). The femoral component was still in its centralizer in 239 patients (75.4%). ORIF was performed in 167 patients (52.7%) and revision in 150 (47.3%).

The two-year reoperation rate for all B fractures was 11.0% (n = 35). The median time to surgery was 3.0 days (IQR 2.0 to 5.0), the median LOS was 18.0 days (IQR 12.0 to 28.0) and 250 patients (78.4%) returned to their usual residence.

**Table V.** Comparison of outcomes (open reduction and internal fixation vs revision for type B1 fractures).

Variable	ORIF	Revision	p-value
Total, n (%)	116 (87.2)	17 (12.8)	
Median days to surgery (IQR)	2.0 (1.0 to 4.0)	4.0 (3.0 to 7.0)	0.003*
Blood transfusion needed in 72 hrs, n (%)	26 (22.4)	7 (41.2)	0.094
Median units of blood transfused (IQR)	2 (1 to 2)	2 (2 to 3)	0.981*
<b>Postoperative destination, n (%)</b>			0.035
Orthopaedic ward	109 (94.0)	13 (76.5)	
High dependency unit	4 (3.4)	3 (17.6)	
Intensive care unit	3 (2.6)	1 (5.9)	
Median LOS, days (IQR)	17.0 (11.0 to 30.0)	19.0 (13.0 to 30.0)	0.708*
Return to usual residence, n (%)	89 (76.7)	17 (100.0)	0.026
Reoperation in 90 days, n (%)	3 (2.6)	4 (23.5)	< 0.001
Reoperation in 2 yrs, n (%)	7 (6.0)	5 (29.4)	0.002
Median time to first reoperation (IQR)	150.0 (54.0 to 450.0)	59.0 (17.0 to 80.0)	0.290*
Median total reoperations, n (IQR)	1 (1 to 2)	1 (1 to 1)	0.428*
Readmissions in 30 days, n (%)	1 (0.9)	1 (5.9)	0.112
Time to readmission, days	19.0	17.0	
Readmission LOS, days	3.0	2.0	
Local complications in 2 yrs, n (%)	10 (8.6)	8 (47.1)	< 0.001
Median time to local complication in 2 yrs, days (IQR)	97.0 (48.0 to 345.0)	88.0 (42.0 to 260.0)	0.859*
Systemic complication in 6 months, n (%)	16 (13.8)	4 (23.5)	0.294
Median time to systemic complication in 6 months (IQR)	15.0 (5.0 to 23.0)	20.0 (6.0 to 42.0)	0.392*
<b>Mortality, n (%)</b>			
30 day	4 (3.4)	0 (0.0)	0.437
1 year	21 (18.1)	1 (5.9)	0.205
Median days to death within 1 year (IQR)	111.0 (46.0 to 202.0)	48.0	0.478*

\*Mann-Whitney U test.

†Chi-squared test.

‡Fisher's exact test.

IQR, interquartile range; LOS, length of stay; ORIF, open reduction and internal fixation.

Postoperative blood transfusion was administered to 97 patients (30.6%) within 72 hours and 43 (13.6%) required critical care admission postoperatively. The 90-day reoperation rate was 5.4% (17 patients), the 30-day readmission rate was 3.8% (12 patients), the two-year local complication rate was 17.4% (55 patients), the six-month systemic complication rate was 16.1% (51 patients), the 30-day mortality rate was 3.2% (10 patients), and the one-year mortality rate was 15.1% (48 patients). By two years, 74 patients (23.3%) had died with a median time to death of 7.5 months (IQR 2.3 to 15.4).

A comparison of the baseline characteristics of the patients, the primary THAs and fractures is shown in Table I. Significantly more patients in the ORIF group had preoperative care home status, a fully cemented THA, well-fixed femoral cement and femoral components which remained in their centralizer compared with the revision group which had significantly more patients with a high-energy injury and a multifragmentary fracture.

The operations which were performed for all B fractures are shown in Table II and the outcomes in Table III. The two-year reoperation rate was significantly higher in the revision compared with the ORIF group (15.3% (n = 23) vs 7.2% (n = 12); p = 0.021, chi-squared test). The two-year reoperation rates by ORIF subtype were 16.7% (n = 1), 9.5% (n = 2), and 6.4% (n = 9) for the cerclage, plate only, and plate and cerclage groups, respectively. There was no significant difference in either the two-year reoperation rate (8.1% (n

= 9) vs 4.0% (n = 2); p = 0.339, Fisher's exact test) or the two-year local complication rate (7.2% (n = 8) vs 12.0% (n = 6); p = 0.318, chi-squared test) between conventional and PFF-specific locking plates, respectively. The median time to surgery, the 72-hour blood transfusion requirement, the postoperative critical care requirement, and two-year local complication rates were significantly higher in the revision group.

The indications for reoperation and readmissions, and the complications are shown in Table IV and Supplementary Table i. The most common local complication and indication for reoperation in the revision group was dislocation. Only 22 patients (14.7%) in the revision group had revision of the acetabular component at the time of surgery for periprosthetic fracture. Of the 13 patients who had a dislocation in the revision group, ten (76.9%) did not undergo revision of the acetabular component and the remaining three (23.1%) had revision with a standard acetabular component. None of the 12 patients who underwent acetabular revision at the time of surgery for periprosthetic fracture with either a dual-mobility (n = 7; 58.3%) or a constrained (n = 5; 41.7%) component had a dislocation. With two-year reoperation for any indication as the endpoint, Kaplan-Meier analysis showed a significantly higher two-year survival for ORIF compared with revision (91.9% (SE 0.023) vs 83.9% (SE 0.031); p = 0.032, log-rank test; Figure 1).

The outcomes of surgery for B1 fractures are shown in Table V. The two-year reoperation rate, the median time to

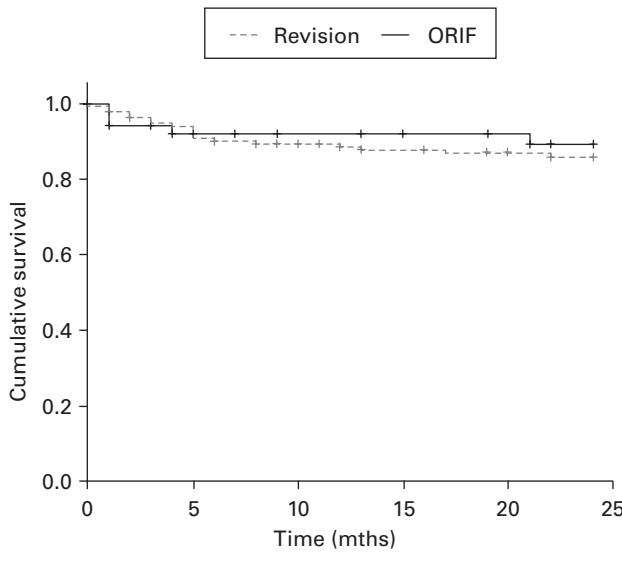


Fig. 3

Kaplan-Meier survival analysis of open reduction and internal fixation (ORIF) versus revision (type B2 and B3 fractures).

surgery, postoperative critical care requirement, 90-day reoperation rate and two-year local complication rate were significantly higher in the revision group. Significantly more patients returned to their usual residence in the revision group. The indications for reoperation, readmissions, and the complications are shown Table VI and Supplementary Table ii. The most common local complication and indication for reoperation in the revision group was dislocation. There was a significantly higher two-year survival after ORIF compared with revision (93.1% (SE 0.025) vs 70.6% (SE 0.111);  $p = 0.001$ , log-rank test; Figure 2).

The outcome of surgery for type B2 and B3 fractures are shown in Table VII. The two-year reoperation rate was similar between the ORIF and revision groups. The median time to surgery, postoperative critical care requirement, and the two-year local complication rate were significantly higher in the revision group. The 30-day readmission rate was significantly higher in the ORIF group. The indications for reoperation and readmissions, and the complications are shown in Table VIII and Supplementary Table iii. The most common local complication in the revision group again was dislocation. Two-year survival rates were similar between the ORIF and revision groups (89.0% (SE 0.047) vs 85.6% (SE 0.032), respectively;  $p = 0.640$ , log-rank test; Figure 3).

## Discussion

This is the largest study investigating surgical outcomes for type B periprosthetic fractures around PTS femoral components. It confirms that for B1 fractures, revision has a significantly higher two-year reoperation rate than ORIF, and that the two-year reoperation rates are similar between the groups for type B2 and B3 fractures. Revision is also associated with a longer time to surgery, higher blood transfusion requirements, higher critical care requirements, and a higher two-year local complication rate. The most common local complication and

**Table VI.** Indications for reoperation and readmissions, and the complications (type B1 fractures).

Variable	ORIF	Revision
Total	116 (87.2)	17 (12.8)
<b>First reoperation indication, n (%)</b>		
Fixation failure	3 (2.6)	0 (0.0)
Local infection	1 (0.9)	1 (5.9)
Dislocation	0 (0.0)	4 (23.5)
Further PFF	1 (0.9)	0 (0.0)
Femoral component loosening	2 (1.7)	0 (0.0)
Total	7 (6.0)	5 (29.4)
<b>First reoperation type, n (%)</b>		
Debridement for infection	1 (0.9)	1 (5.9)
Reduction of dislocated THA	0 (0.0)	2 (11.8)
Revision ORIF	3 (2.6)	0 (0.0)
ORIF of further PFF	1 (0.9)	0 (0.0)
Revision THA (both components)	0 (0.0)	1 (0.0)
Revision THA (femoral component only)	2 (1.7)	0 (0.0)
Revision THA (acetabular component only)	0 (0.0)	1 (0.0)
Total	7 (6.0)	5 (29.4)
<b>Readmissions in 30 days, n (%)</b>		
Loose femoral component	1 (0.9)	0 (0.0)
Seizure	0 (0.0)	1 (5.9)
Total	1 (0.9)	1 (5.9)
<b>Local complication in 2 yrs, n (%)</b>		
Chronic pain related to plate	1 (0.9)	0 (0.0)
Dislocation	0 (0.0)	4 (23.5)
Fixation failure	3 (2.6)	0 (0.0)
Further PFF	1 (0.9)	2 (11.8)
Femoral component loosening	3 (2.6)	0 (0.0)
Local infection	1 (0.9)	0 (0.0)
Nonunion	0 (0.0)	2 (11.8)
Sciatic nerve injury	1 (0.9)	0 (0.0)
Total	10 (8.6)	8 (47.1)

ORIF, open reduction and internal fixation; PFF, periprosthetic femoral fracture; THA, total hip arthroplasty.

indication for reoperation following revision is dislocation. When revision is undertaken, revision of the acetabular component to either a dual-mobility or constrained component should be considered. Due to lower reoperation rates and hospital resource requirements, our findings support the use of ORIF rather than revision for type B fractures, providing anatomical reconstruction can be achieved. This challenges the practice of exclusively performing revision for fractures around PTS components based on the assumption that these components are loose due to their taper-slip design.

Expected differences between the baseline characteristics of the two groups were observed. The ORIF group had more care home residents, reflecting increased frailty, which may have influenced surgical decision-making with a preference for ORIF over revision surgery in some patients. The ORIF group included more patients with well-fixed femoral cement and components which remained within their centralizer. It is not clear why there were more cemented acetabular components in the ORIF group, but this is unlikely to have influenced the choice of treatment. The revision group had more high-energy injuries and multifragmentary fractures, which are less likely to

**Table VII.** Comparison of outcomes (open reduction and internal fixation vs revision for B2 and B3 fractures).

Variable	ORIF	Revision	p-value
Total, n	51	133	
Median days to surgery (IQR)	3.0 (1.0 to 6.0)	4.0 (2.0 to 7.0)	0.039*
Blood transfusion needed in 72 hrs, n (%)	16 (31.4)	48 (36.1)	0.548†
Median units of blood transfused (IQR)	2 (2 to 2.75)	2 (1 to 2)	0.301*
<b>Postoperative destination, n (%)</b>			< 0.001†
Orthopaedic ward	51 (100.0)	101 (75.9)	
High dependency unit	0 (0.0)	14 (10.5)	
Intensive care unit	0 (0.0)	18 (13.5)	
Median LOS, days (IQR)	20.0 (12.0 to 29.0)	19.0 (13.0 to 24.0)	0.414*
Return to usual residence, n (%)	39 (76.5)	105 (78.9)	0.715†
Reoperation in 90 days, n (%)	3 (5.9)	7 (5.3)	0.558
Reoperation in 2 yrs, n (%)	5 (9.8)	18 (13.5)	0.341
Median days to first reoperation (IQR)	40.0 (17.0 to 379.0)	149.0 (61.0 to 268.0)	0.233*
Median total reoperations (IQR)	1 (1 to 2)	1 (1 to 2)	0.629*
Readmissions in 30 days, n (%)	6 (11.8)	4 (3.0)	0.029
Median time to readmission (IQR)	8.0 (3.0 to 18.0)	5.0 (2.0 to 7.0)	0.389*
Median readmission LOS (IQR)	1.0 (1.0 to 14.0)	8.0 (2.0 to 24.0)	0.194*
Local complications in 2 yrs, n (%)	5 (9.8)	32 (24.1)	0.031†
Median days to local complication in 2 yrs (IQR)	68.0 (27.0 to 161.0)	74.0 (27.0 to 156.0)	0.929*
Systemic complication in 6 months, n (%)	11 (21.6)	20 (15.0)	0.289†
Median days to systemic complication in 6 months (IQR)	13.0 (5.0 to 19.0)	8.0 (6.0 to 21.0)	0.605*
<b>Mortality, n (%)</b>			
30 days	4 (7.8)	2 (1.5)	0.051
1 year	9 (17.6)	17 (12.8)	0.396†
Median days to death within 1 year (IQR)	37.0 (22.0 to 162.0)	187.0 (54.0 to 324.0)	0.063*

\*Mann-Whitney U test.

†Chi-squared test.

‡Fisher's exact test.

IQR, interquartile range; LOS, length of stay; ORIF, open reduction and internal fixation.

be treated with ORIF due to the risk of subsequent loosening of the femoral component.

The two-year reoperation rate for all type B fractures was 11.0%, consistent with a recent systematic review of periprosthetic fractures around PTS femoral components, which reported a reoperation rate of 11.4%.<sup>24</sup> In the present study, the two-year reoperation rate of the ORIF group was 7.2%, which is also similar to previous reports.<sup>19,21,25</sup> Like others, this study did not show any benefit of periprosthetic fracture-specific locking plates over conventional non-locking plates and this may have implications for cost-savings.<sup>15,25</sup> In effect, placing non-locked cortical screws into cement through a conventional plate creates a fixed-angled device in which screws cannot loosen independently. This may explain the lack of advantage of fracture-specific locking plates. The higher reoperation rate of 15.3% in the revision group was predominantly due to dislocation as evidenced by an early reduction in cumulative survival compared with the ORIF group. Dislocation can occur due to abductor dysfunction, incorrect restoration of the offset and limb length discrepancy. The overall dislocation rate following revision was 8.0%, which is lower than previously reported.<sup>20,21</sup> If this complication could be avoided altogether, outcomes may have been at least equivalent to ORIF. Only 14.7% of patients in the revision group underwent concurrent revision of the acetabular component, and none of those whose revision involved either a dual-mobility or constrained component dislocated. The

risk of dislocation may therefore be mitigated by their use but this must be balanced against the increased risks of bleeding and infection associated with increased operating time.

Longer waiting times for revision compared with ORIF were consistently observed and these delays are likely to be related to the availability of arthroplasty teams with the appropriate revision expertise. Surgical waiting times vary and there is some evidence that longer waiting times are associated with poorer outcomes, such as increased rates of transfusion, LOS, and mortality.<sup>26,27</sup> Revision surgery is more complex than ORIF and this explains the higher blood transfusion and critical care requirements observed in this group. The mean LOS was similar in the two groups, which was an unexpected finding as revision femoral components allow full weightbearing postoperatively whereas some surgeons may restrict weightbearing following ORIF. However, LOS is recognized to be complex and multifaceted and includes many patient-related factors and aspects of social care. These issues are pertinent to upcoming regional service reconfigurations within the NHS in the UK for revision arthroplasty networks in an attempt to improve the outcomes for patients undergoing this complex surgery.<sup>28,29</sup>

This study is strengthened by its multicentre, consecutive, and large dataset which enhances the generalizability of its conclusions. The differences in baseline characteristics which were seen between the ORIF and revision groups, although expected, represent a limitation. An attempt was made to

**Table VIII.** Indications for reoperation and readmissions, and the complications (type B2 and B3 fractures).

Variable	ORIF, n (%)	Revision, n (%)
Total (184)	51	133
<b>First reoperation (indication)</b>		
Fixation failure	1 (1.9)	0 (0.0)
Local infection	2 (3.9)	1 (0.8)
Dislocation	1 (1.9)	8 (6.0)
Further PFF	0 (0.0)	3 (2.3)
Femoral component loosening	1 (1.9)	3 (2.3)
Haematoma	0 (0.0)	2 (1.5)
Nonunion	0 (0.0)	1 (0.8)
Total	5 (9.8)	18 (13.5)
<b>First reoperation (type)</b>		
Debridement for infection	2 (3.9)	1 (0.8)
Evacuation of haematoma	0 (0.0)	2 (1.5)
Reduction of dislocated THA	1 (1.9)	6 (4.5)
Revision ORIF	1 (1.9)	0 (0.0)
ORIF of further PFF	0 (0.0)	2 (1.5)
Revision THA (both components)	1 (1.9)	3 (2.3)
Revision THA (femoral component only)	0 (0.0)	4 (3.0)
Revision THA (acetabular component only)	0 (0.0)	0 (0.0)
Total	5 (9.8)	18 (13.5)
<b>Readmissions in 30 days</b>		
Sepsis	1 (1.9)	1 (0.8)
Dislocation	0 (0.0)	1 (0.8)
Chest infection	0 (0.0)	1 (0.8)
Further PFF	0 (0.0)	1 (0.8)
Fall	1 (1.9)	0 (0.0)
Local infection	1 (1.9)	0 (0.0)
Wound leak	1 (1.9)	0 (0.0)
Pain	1 (1.9)	0 (0.0)
Urinary tract infection	1 (1.9)	0 (0.0)
Total	6 (11.8)	4 (3.0)
<b>Local complication in 2 yrs</b>		
Chronic pain related to plate	0 (0.0)	1 (0.8)
Dislocation	1 (1.9)	9 (6.8)
Fixation failure	1 (1.9)	1 (0.8)
Further PFF	1 (1.9)	6 (4.5)
Haematoma	0 (0.0)	2 (1.5)
Heterotopic ossification	0 (0.0)	1 (0.8)
Femoral component loosening	1 (1.9)	5 (3.8)
Local infection	1 (1.9)	2 (1.5)
Intraoperative PFF	0 (0.0)	2 (1.5)
Symptomatic leg length difference	0 (0.0)	1 (0.8)
Nonunion	0 (0.0)	2 (1.5)
Total	5 (9.8)	32 (24.1)

ORIF, open reduction and internal fixation; PFF, periprosthetic femoral fracture; THA, total hip arthroplasty.

match the groups but the numbers became too small for meaningful comparison. There may also be some variation in the subclassification of fractures but this was managed by providing standardized definitions to all study centres.<sup>30</sup> The success of surgery as measured by the absence of reoperation alone does not reflect function and any future prospective study should include PROMs for a more holistic analysis.

In conclusion, revision surgery for type B periprosthetic fractures around PTS femoral components is associated with significantly higher reoperation rates, longer surgical waiting times, higher blood transfusion requirements, higher

critical care requirements, and higher local complication rates compared with ORIF. ORIF is a safe option for the management of these fractures, providing that anatomical reconstruction can be achieved. If revision is performed, the risk of postoperative dislocation should be mitigated by the use of a dual-mobility or constrained acetabular component.



### Take home message

- For type B periprosthetic fractures around cemented polished taper-slip stems, revision surgery has higher reoperation rates compared to open reduction and internal fixation (ORIF).
- Providing anatomical reconstruction can be achieved, ORIF is a safe and more resourceful option.
- Single component revision (involving the femoral stem only) has a high rate of postoperative dislocation.
- If revision is performed, the risk of dislocation should be mitigated with a dual-mobility or constrained cup.

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### Supplementary material



Tables displaying systemic complications at six months.

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**Ethical review statement:**

NHS Health Research Authority ethical approval was obtained for this multicentre observational cohort study (REC 21/PR/0856).

This article was primary edited by J. Scott.

## ■ HIP

# Long-term implant survival following hemiarthroplasty for fractured neck of femur

AN ANALYSIS OF COMMONLY USED PROSTHESES FROM THE AUSTRALIAN NATIONAL JOINT REPLACEMENT REGISTRY

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### Aims

Several different designs of hemiarthroplasty are used to treat intracapsular fractures of the proximal femur, with large variations in costs. No clinical benefit of modular over monoblock designs has been reported in the literature. Long-term data are lacking. The aim of this study was to report the ten-year implant survival of commonly used designs of hemiarthroplasty.

### Methods

Patients recorded by the Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) between 1 September 1999 and 31 December 2020 who underwent hemiarthroplasty for the treatment of a hip fracture with the following implants were included: a cemented monoblock Exeter Trauma Stem (ETS), cemented Exeter V40 with a bipolar head, a monoblock Thompsons prosthesis (Cobalt/Chromium or Titanium), and an Exeter V40 with a Unitrax head. Overall and age-defined cumulative revision rates were compared over the ten years following surgery.

### Results

A total of 41,949 hemiarthroplasties were included. Exeter V40 with a Unitrax head was the most commonly used ( $n = 20,707$ , 49.4%). The overall rate of revision was small. A total of 28,201 patients (67.2%) were aged  $> 80$  years. There were no significant differences in revision rates across all designs of hemiarthroplasty in patients of this age at any time. The revision rates for all designs were  $< 3.5\%$ , three years postoperatively. At subsequent times the ETS and Exeter V40 with a bipolar head performed well in all age groups. The unadjusted ten-year mortality rate for the whole cohort was 82.2%.

### Conclusion

There was no difference in implant survival between all the designs of hemiarthroplasty in the first three years following surgery, supporting the selection of a cost-effective design of hemiarthroplasty for most patients with an intracapsular fracture of the hip, as determined by local availability and costs. Beyond this, the ETS and Exeter bipolar designs performed well in all age groups.

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### Introduction

Worldwide, proximal femoral fractures cause a considerable public health burden. It is estimated that their global incidence will double during the next 20 to 30 years.<sup>1</sup> These injuries nearly always require surgery.<sup>2,3</sup> Hemiarthroplasty of the hip is the most common procedure recorded in the National Hip Fracture Database (NHFD) for patients with this injury.<sup>4</sup> The most recent annual report from the Australian Orthopaedic

Association National Joint Replacement Registry (AOANJRR) showed a one-year rate of mortality of 29% for these patients.<sup>5</sup> In the UK, a fracture of the hip is associated with hospital costs of £14,163 and represents a total cost to health and social services of  $> £1$  billion/year.<sup>6</sup> A report from the NHS Hip Fracture Anaesthesia Network estimated that by 2033, approximately 100,000 patients will require surgery for a fractured neck of femur in England annually, requiring an additional 287 to

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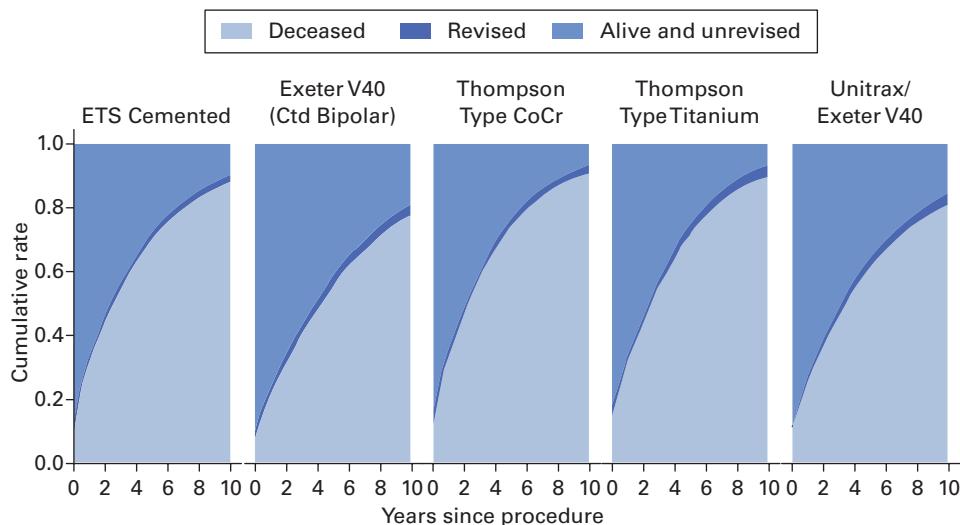


Fig. 1

Cumulative rate of mortality and revision by design of hemiarthroplasty. CoCr, Cobalt/Chromium; ETS, Exeter Trauma Stem.

**Table I.** Hemiarthroplasties included in the study and the number of revision procedures.

Model	Revised, n	Total, n
ETS Cemented	78	3,565
Exeter V40 (Cemented Bipolar)	343	11,494
Thompson Type CoCr	100	3,746
Thompson Type Titanium	90	2,437
Exeter Unitrax	649	20,707
Total	1,260	41,949

CoCr, Cobalt/Chromium.

474 hospital beds across the health service.<sup>7</sup> After adjusting for inflation, it is estimated that the total annual cost of the treatment of patients with a hip fracture will be between £3.6 and £5.6 billion.<sup>8</sup>

Cemented hemiarthroplasty results in a better quality of life and a lower risk of periprosthetic fracture than when using an uncemented hemiarthroplasty.<sup>9,10</sup> A recent freedom of information study reported that 19 different designs of hemiarthroplasty were used in the UK, with the most frequently used being the monoblock Exeter Trauma Stem (ETS) (Stryker, USA) and the Exeter V40 stem with a monopolar modular Unitrax head (Stryker).<sup>11</sup> The NHFD annual report has previously highlighted the wide variation in the costs of the implants used, with simple monoblock designs typically being substantially cheaper than more complex modular designs.<sup>4</sup> With the number of hemiarthroplasties undertaken expected to rise each year, the cost-effectiveness of the choice of implant is critical.

It has been shown that measures of the quality of life may be the most important outcomes for patients with a hip fracture.<sup>12</sup> The National Institute for Health and Care Excellence (NICE) 2011 guidance recommended the use of a ‘proven’ design of femoral stem for hip hemiarthroplasty with an Orthopaedic Data Evaluation Panel (ODEP) rating.<sup>13</sup> However, the most recent 2023 update from NICE removed this aspect from the

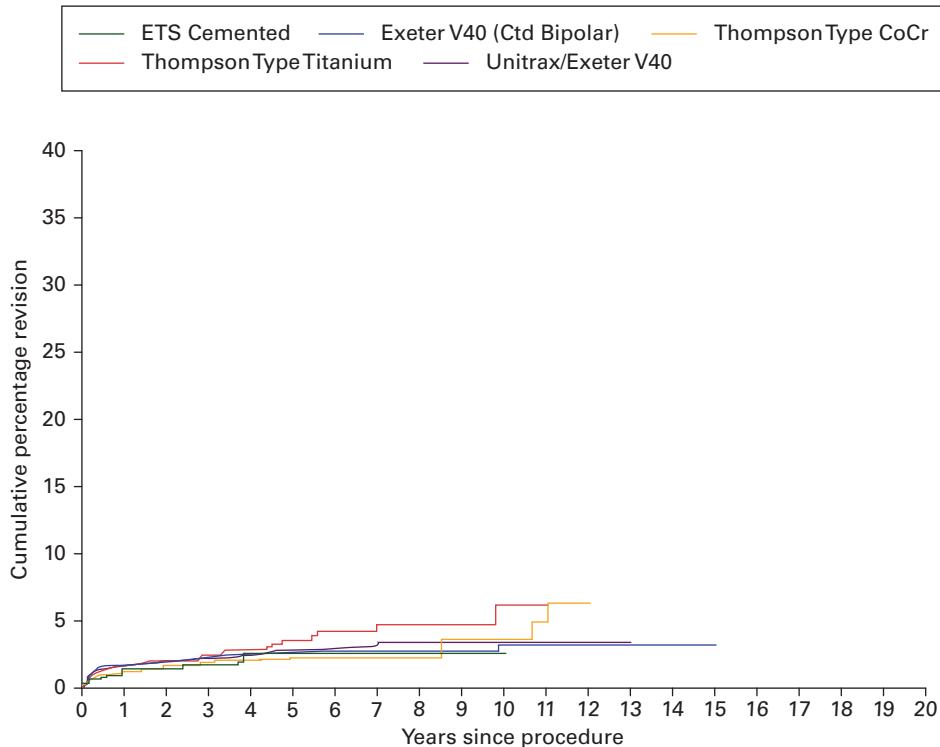
guidelines, recognizing that ODEP does not specifically rate designs of hemiarthroplasty, and now recommends that hospitals use a single type of cemented femoral component for hemiarthroplasty, taking into account overall costs.<sup>13</sup> No difference has been shown in randomized controlled trials in the quality of life between the use of cemented Thompsons and the ETS,<sup>14</sup> or the Exeter V40 Unitrax modular design.<sup>15</sup> It is also, however, acknowledged that long-term outcomes following hemiarthroplasty are lacking, and NICE highlights this as a key recommendation for future research.<sup>13</sup>

The AOANJRR has collected data on the use of hemiarthroplasty in these patients and outcomes since its inception. Australian trauma care reflects similar practices in the UK. The aim of this study was to analyze this national dataset for commonly used designs of cemented hemiarthroplasty in the management of hip fractures, comparing long-term patient and implant survival, to highlight implications for practice in the UK.

## Methods

The AOANJRR began collecting data on 1 September 1999, with complete nationwide collection commencing in 2002 to include almost 100% of the arthroplasties performed in Australia. Registry data are validated against data provided by state and territory health departments in Australia using a sequential multilevel matching process. A matching programme is run monthly to search for all primary and revision arthroplasties recorded in the registry that involve the same side and joint of the same patient, thus enabling each revision to be linked to the primary procedure. Data are also matched biannually with the Australian Government Department of Health and Ageing’s National Death Index to obtain the date of death.<sup>16</sup>

This study included all patients recorded in the registry who had undergone a cemented hemiarthroplasty of the hip for the treatment of a hip fracture up to 31 December 2020, using the



Number at risk		0 yr	1 yr	2 yrs	3 yrs	4 yrs	5 yrs	6 yrs	7 yrs	8 yrs	9 yrs	10 yrs
> 80 ETS Cemented		2562	1598	1223	918	648	444	305	216	155	102	56
Exeter V40 (Ctd Bipolar)		7167	4697	3495	2619	1973	1395	981	677	474	340	235
Thompson Type CoCr		2698	1663	1303	994	749	560	392	269	193	136	98
Thompson Type Titanium		1807	1170	916	705	522	368	260	177	117	79	63
Unitrax/Exeter V40		13967	8770	6535	4761	3389	2316	1503	1017	652	401	235
Number at risk		11 yrs	12 yrs	13 yrs	14 yrs	15 yrs	16 yrs	17 yrs	18 yrs	19 yrs	20 yrs	
> 80 ETS Cemented		34	14	7	5	1	1	0	0	0	0	0
Exeter V40 (Ctd Bipolar)		165	120	79	58	44	27	17	10	3	0	0
Thompson Type CoCr		65	51	35	29	24	22	15	11	5	0	0
Thompson Type Titanium		47	34	28	24	18	17	14	10	8	2	0
Unitrax/Exeter V40		155	96	54	27	13	8	4	2	0	0	0

Fig. 2

Cumulative percentage revision of hemiarthroplasty by design in patients aged > 80 years. CoCr, Cobalt/Chromium.

following prostheses: ETS (monopolar monoblock; Stryker); Exeter V40 with bipolar head (bipolar modular; Stryker); Thompsons (Cobalt/Chromium) (monopolar monoblock; multiple manufacturers); Thompsons (Titanium) (monopolar monoblock; multiple manufacturers); and Exeter V40 with Unitrax head (monopolar modular; Stryker).

**Statistical analysis.** The annual cumulative percentages of revision procedures were recorded using Kaplan-Meier estimates of survivorship. An accompanying 95% confidence interval (CI) was calculated using unadjusted pointwise Greenwood estimates. The registry defines revision as any reoperation in which one or more prosthetic components are replaced, removed, or added. Secondary

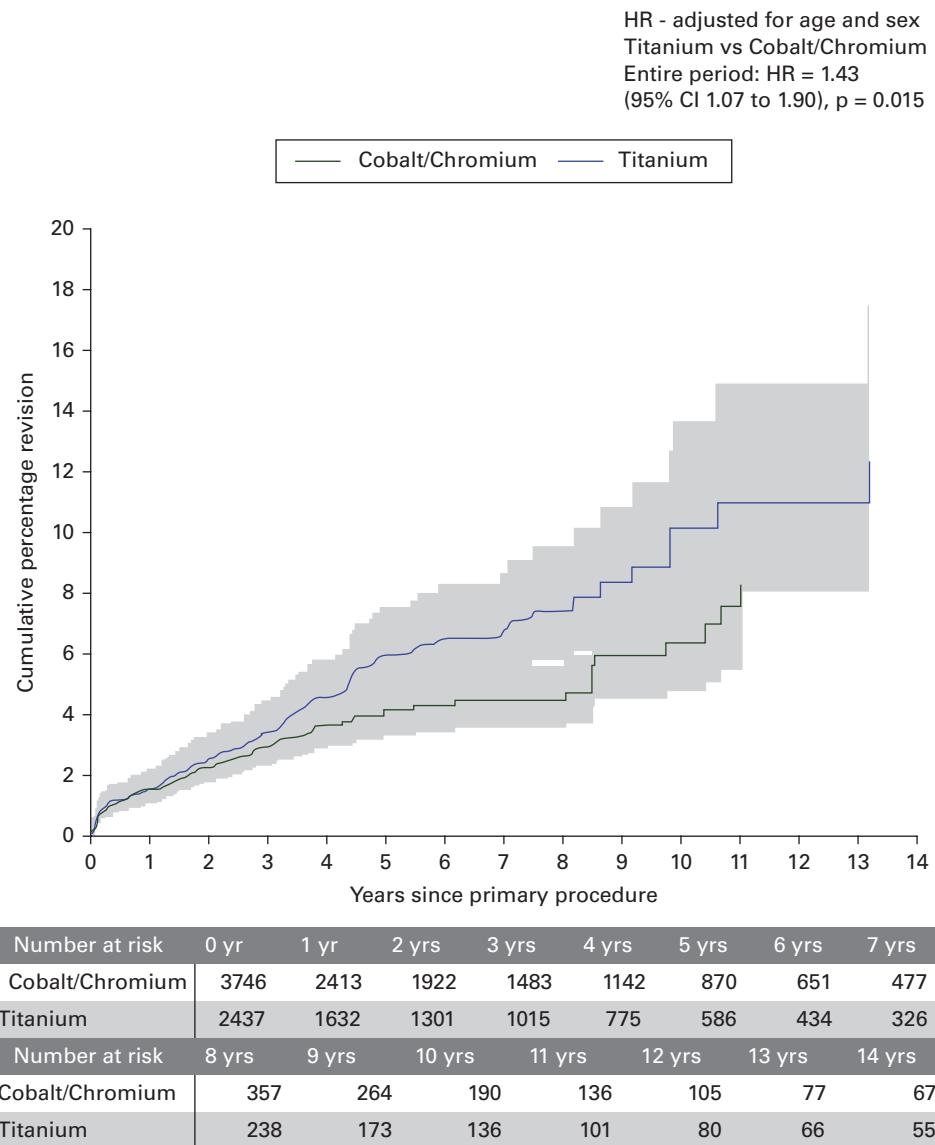


Fig. 3

Cumulative revision of Thompsons hemiarthroplasty by type of metal. CI, confidence interval.

outcome measures were the indications for revision and cumulative ten-year rates of mortality. Patients were censored at the time of death or closure of the database at the end of the study period. The outcomes were stratified by three age groups – < 70, 70 to 80, and > 80 years – for each design of hemiarthroplasty. Hazard ratios (HRs) were calculated from Cox proportional hazards models, and significance calculated using two-tailed tests at the 5% level of significance. Analysis was performed using SAS version 9.4 (SAS Institute, USA).

## Results

A total of 41,949 hemiarthroplasties were recorded. Exeter Unitrax was the most commonly used ( $n = 20,707$ ; 49.4%) followed by Exeter bipolar ( $n = 11,494$ ; 27.4%). The number of

hemiarthroplasties which were included and the number of revisions are shown in Table I. A total of 28,201 patients (67.2%) were aged > 80 years at the time of surgery.

The unadjusted ten-year mortality rate was 82.2%. The cumulative incidence of mortality ranged from 40.9% for the Exeter bipolar to 58.4% for the Cobalt/Chromium Thompsons hemiarthroplasty at three years following surgery, and between 77.9% and 90.9% at ten years (Supplementary Table i, Figure 1).

The overall rate of revision was small. For patients aged > 80 years, there were no significant differences in revision rates across all designs, and all had low cumulative revision rates at three years (95% CI 1.4 to 3.4) and ten years (95% CI 1.8 to 6.9) postoperatively (Supplementary Table ii, Figure 2). Across the whole cohort, there were no differences between the revision

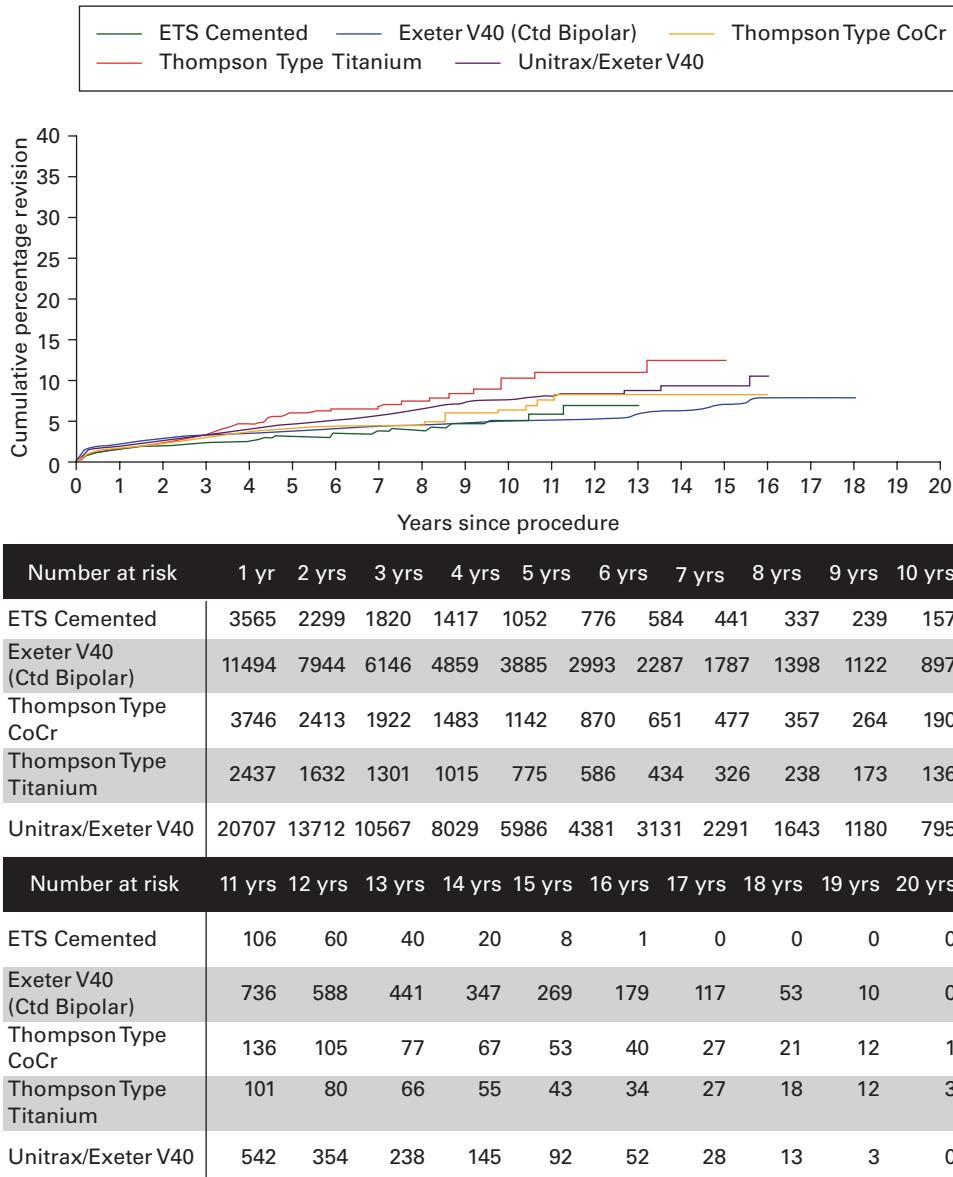


Fig. 4

Cumulative percentage revision of hemiarthroplasty by design. CoCr, Cobalt/Chromium; ETS, Exeter Trauma Stem.

rates at one and three years postoperatively. However, by five years, the Exeter Unitrax (4.6% (95% CI 4.2 to 5.0)) and Titanium Thompsons (5.9% (95% CI 4.7 to 7.5)) designs had significantly higher revision rates than the ETS (3.0% (95% CI 2.3 to 3.9)). The revision rate for the Titanium Thompsons was significantly higher than that of the Cobalt/Chromium Thompsons design (HR 1.43 (95% CI 1.07 to 1.90),  $p = 0.015$ ) (Figure 3). The ETS and Exeter bipolar designs performed well across all age groups. By ten years, the Exeter bipolar design had the lowest revision rate (5.0% (95% CI 4.4 to 5.8)), although this was not significantly lower than the ETS (5.1% (95% CI 3.6 to 7.1)) or the Cobalt/Chromium Thompsons designs (6.3% (95% CI 4.7 to 8.5)). These results are shown in Figure 4 and Supplementary Table ii.

The most common indication for the revision of modular implants was infection, accounting for 25.6% (166/649) for the Exeter Unitrax and 28.9% (99/343) for the Exeter bipolar designs. Dislocation was the most common indication for revision of the ETS design (28.2% (22/78)). Thompsons monoblock hemiarthroplasties were revised most often for aseptic loosening, although this was more common with the Titanium Thompsons (40.0% (36/90) compared with 28.0% (28/100) for the Cobalt/Chromium Thompsons). The rate of revision for periprosthetic fracture was low for all designs, ranging from 0.3% to 0.5%. The indications for revision by design of hemiarthroplasty are shown in Supplementary Table iii.

## Discussion

In this registry-based study, we found no difference in implant survival between all designs of hemiarthroplasty, in patients aged > 80 years. There is some evidence to suggest that patients aged ≤ 80 years who undergo hemiarthroplasty for a hip fracture are less likely to have a revision if the ETS or the Exeter bipolar designs are used. Crucially, there were no differences in revision rates across the whole cohort, one and three years postoperatively, when all designs of hemiarthroplasty were compared. The lowest revision rate, ten years postoperatively, was with the Exeter bipolar design, although this was not significantly lower than for either the ETS or Cobalt/Chromium Thompsons design.

Despite the Exeter Unitrax being one of the most common designs of hemiarthroplasty used in Australia and the UK,<sup>4,11,13</sup> our findings show that its use is associated with a significantly higher revision rate at ten years than the Exeter bipolar design. These results support the introduction of the rationalization of the design of hemiarthroplasty that should be used in these patients.

The Exeter V40 stem has shown excellent long-term survivorship in registries, and satisfies the highest ODEP rating criteria when used as a total hip arthroplasty (THA) construct.<sup>17</sup> However, while implant survival may affect decision-making in THA, it has been suggested that pain and function are the most important outcome measures for patients who undergo surgery for a fracture of the hip.<sup>12</sup> We found similar implant survivorship between all designs of hemiarthroplasty at one and three years postoperatively. It is noted that at three years postoperatively, approximately 50% of these patients have died. No clinical benefit of modular over monoblock hemiarthroplasty designs has been reported in the literature. As there are no clinical differences, and survivorship is equivalent between the two, the evidence would support the selection of either design for most patients. NICE recognizes that although there are no cost-effectiveness studies, the costs of different designs of hemiarthroplasty vary considerably. Long-term data from our study support the appropriate procurement of the most cost-effective implant, as determined by local availability and costs.

A previous study involving 1,670 cemented Thompsons hemiarthroplasties reported a five-year implant survival of 95.4%.<sup>18</sup> Elsewhere, revision rates of this hemiarthroplasty as low as 1.2% at five years have been reported or,<sup>19</sup> more recently, cumulative survival of 90.3% at ten years.<sup>20</sup> We found a ten-year revision rate of 6.3% for Cobalt/Chromium Thompsons and 10.1% for Titanium Thompsons (HR 1.43 (95% CI 1.07 to 1.90), p = 0.015) (Figure 3). This significant difference appears to be attributed to a higher incidence of aseptic loosening in Titanium Thompsons (40.0% (36/90) of revision procedures) compared with Cobalt/Chromium Thompsons (28.0% (28/100)). Physical characteristics of implants include biocompatibility, Young's modulus of elasticity, strength, and resistance to corrosion, and each influence their fixation and the development of aseptic loosening.<sup>21</sup> Anecdotally, surgeons also report problems revising Titanium Thompsons hemiarthroplasties resulting in a greater than expected bone loss, but we are not aware that this has been reported in the literature.

Nevertheless, we would advise against the use of Titanium Thompsons hemiarthroplasties and suggest using the Cobalt/Chromium Thompsons instead.

Dislocation was the most common indication for revision with the ETS hemiarthroplasty. A dislocation rate of 1% when using this implant has recently been reported, with 90% of dislocations occurring in the first two months postoperatively.<sup>22</sup> Poor soft-tissue tension in elderly patients may impair stability, particularly in those with neurological conditions.<sup>23</sup> However, this early incidence of dislocation suggests that both surgical and implant factors may be implicated. Both Thompsons and the ETS implants are monoblock; however, the design of any Exeter implant allows for freedom to adjust version and leg length. In the hands of an inexperienced surgeon, this allows more potential margin for error, compared with a collared, more anatomical implant, such as the Thompsons. Moreover, the single offset of 40 mm of the ETS implant may be a compromise for some patients.

Infection was the most common indication for revision in modular implants. There are many risk factors for the development of deep infection after hemiarthroplasty, however this finding may in part be explained by longer operating times for modular implants.<sup>24,25</sup> The mean operating time in the WHITE3 trial was 80 minutes (42 to 205) for the Exeter Unitrax and 70 minutes (27 to 197) for the Thompsons.<sup>15</sup>

It has previously been reported that polished tapered stems, such as the Exeter in THA, have a higher rate of periprosthetic fracture compared with composite beam stems such as the Charnley.<sup>26,27</sup> This difference has also been reported in hemiarthroplasty.<sup>28</sup> However, we found no difference in revision rates for periprosthetic fracture among all designs of hemiarthroplasty. The rate of periprosthetic fracture should perhaps no longer be used as an argument for rationalizing the choice of implant, as previously reported.<sup>26-28</sup>

Patients receiving monoblock implants had similarly high mortality rates at ten years following surgery, suggesting that these implants were used in frailer patients. In contrast, patients receiving modular implants had a lower mortality at ten years (Supplementary Table i, Figure 1). This suggests that the choice of implant at the time of preoperative assessment is influenced by the patient's health and perceived longevity. This is demonstrated well in Figure 1, where substantially more patients are alive and have not undergone revision in the Exeter V40 cemented bipolar and Exeter Unitrax groups. The Exeter bipolar hemiarthroplasty had the lowest cumulative revision rate despite the data suggesting that it was used in younger patients. A post hoc analysis of the HEALTH trial found that, even in the fittest patients, there is no clinical benefit to THA compared with hemiarthroplasty, in the first two years postoperatively.<sup>29</sup> While the mid- and long-term results of the HEALTH trial are awaited, the results of our study may support the use of Exeter bipolar hemiarthroplasty in younger patients.

This study has limitations. The registry only records revision procedures when a component is added or removed, and does not record reoperations or complications. We therefore may have under-reported dislocations treated with closed reduction, infection treated with washout only, or

periprosthetic fractures treated with internal fixation. While our aim was to report long-term implant survival, it should be noted that ten-year mortality rates are mostly > 80%, and therefore the number of patients eligible for revision surviving beyond ten years is small. There may also be some patients in whom the cause of death was implant-related, but the patient was too unwell to undergo further surgery.

We have used Kaplan-Meier estimates of survivorship and acknowledge that the mortality rate is high, which can lead to an overestimation of the rate of revision.<sup>30</sup> However, our aim was to examine the different designs of hemiarthroplasty used for the same condition in an old age group, and we do not believe that the use of a competing risk model would have altered the results. These data from the AOANJRR do not account for revision procedures that occur in Australian emigrants. However, given the age group, it is likely that this number is extremely small and would be unlikely to alter the results.

In conclusion, in the first three years following surgery for a hip fracture, there is no difference in implant survival between all designs of hemiarthroplasty which we studied. Approximately 50% of these patients have died during the first three postoperative years. For patients with a life expectancy of ≤ three years, these data support the selection of the most cost-effective implant. For those with a life expectancy beyond this, we found that the ETS and Exeter bipolar designs performed well among all age groups. This research addresses the recommendation by NICE to study long-term outcomes for different designs of hemiarthroplasty and supports the procurement of the most cost-effective implant, for most patients, as determined by local availability and costs.



### Take home message

- This study addresses the recommendation by the National Institute for Health and Care Excellence (NICE) to study long-term outcomes for hip hemiarthroplasty implants.
- The results support appropriate procurement of the most cost-effective implant, for the majority of hip fracture patients, as determined by local availability and costs.

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### Supplementary material



- Tables showing cumulative mortality rates for hemiarthroplasty by type, and annual cumulative percent revision of hemiarthroplasty by type and age.

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The datasets generated and analyzed in the current study are not publicly available due to data protection regulations. Access to data is limited to the researchers who have obtained permission for data processing. Further inquiries can be made to the corresponding author.

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## ■ HIP

# The outcome of subsequent revisions after primary total hip arthroplasty in 1,049 patients aged under 50 years

A SINGLE-CENTRE COHORT STUDY WITH A FOLLOW-UP OF MORE THAN 30 YEARS

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### Aims

The aim of this study was to determine the outcome of all primary total hip arthroplasties (THAs) and their subsequent revision procedures in patients aged under 50 years performed at our institution.

### Methods

All 1,049 primary THAs which were undertaken in 860 patients aged under 50 years between 1988 and 2018 in our tertiary care institution were included. We used cemented implants in both primary and revision surgery. Impaction bone grafting was used in patients with acetabular or femoral bone defects. Kaplan-Meier analyses were used to determine the survival of primary and revision THA with the endpoint of revision for any reason, and of revision for aseptic loosening.

### Results

The mean age of the patients at the time of the initial THA was 38.6 years (SD 9.3). The mean follow-up of the THA was 8.7 years (2.0 to 31.5). The rate of survival for all primary THAs, acetabular components only, and femoral components only at 20 years' follow-up with the endpoint of revision for any reason, was 66.7% (95% confidence interval (CI) 60.5 to 72.2), 69.1% (95% CI 63.0 to 74.4), and 83.2% (95% CI 78.1 to 87.3), respectively. A total of 138 revisions were performed. The mean age at the time of revision was 48.2 years (23 to 72). Survival of all subsequent revision procedures, revised acetabular, and revised femoral components at 15 years' follow-up with the endpoint of revision for any reason was 70.3% (95% CI 56.1 to 80.7), 69.7% (95% CI 54.3 to 80.7), and 76.2% (95% CI 57.8 to 87.4), respectively. A Girdlestone excision arthroplasty was required in six of 860 patients (0.7%).

### Conclusion

The long-term outcome of cemented primary and subsequent revision THA is promising in these young patients. We showed that our philosophy of using impaction bone grafting in patients with acetabular and femoral defects is a very suitable option when treating young patients. Surgeons should realize that knowledge of the outcome of subsequent revision surgery, which is inevitable in young patients, must be communicated to this group of patients prior to their initial THA.

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### Introduction

Total hip arthroplasty (THA) is one of the most successful operations, improving the life of millions of people,<sup>1</sup> and increasingly being

considered in young patients. By the year 2030, 52% of primary THAs are expected to be undertaken in patients aged < 65 years, with the greatest increase in those aged between 45 and 55 years.<sup>2</sup>

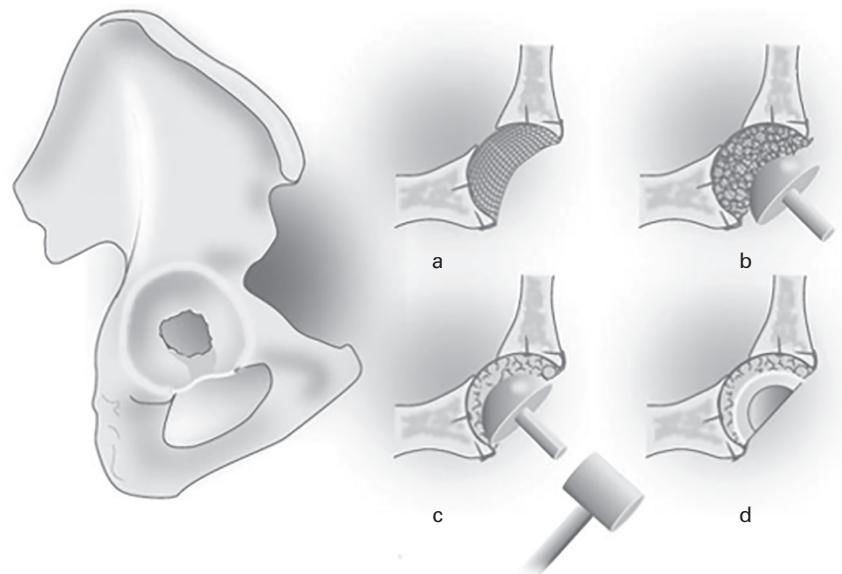


Fig. 1

Acetabular impaction bone grafting. a) A metal mesh is used to close the medial acetabular defect and a superolateral rim mesh is used to cover a superolateral defect. Meshes are fixed with screws. b) A femoral head is morselized to provide bone chips, which are impacted into the reconstructed acetabulum. c) The chips are compressed layer by layer. d) Cement is pressurized into the graft before the component is implanted.

The short-term success after THA is attractive to young patients, as pain is usually dramatically reduced, function is restored, and quality of life is improved. However, for those aged < 55 years, the survival with the endpoint of revision of the implant for any reason has been shown to be inferior when compared with patients aged > 70 years, in many studies.<sup>3-5</sup> The main reasons for higher revision rates in younger patients include the fact that more are undertaken in those with acetabular and/or femoral defects, who have higher demands and activity levels, leading to early wear and loosening. Additionally, due to their young age at the time of the initial surgery, these patients will usually outlive their primary THA.

Therefore, the real focus in studying outcomes of THA in young patients should be on the outcome of the subsequent revision surgery. Only successful revision will keep these patients mobile. In a study by Bayliss et al.,<sup>6</sup> in which lifetime revision risk was used to describe the risk of revision following THA, the problems faced by younger patients were clearly outlined. For those aged between 50 and 54 years, the lifetime risk of revision increased up to 29%, compared with 5% in patients aged > 70 years, with many revisions being performed within five years of the initial surgery. Revisions performed within five years after surgery also have a high risk of re-revision.<sup>5</sup> These numbers are worrying and show the importance of more long-term (re-)revision data, which are still lacking in young patients. To our knowledge, only two studies have reported the long-term outcome of revision THA in patients aged < 55 years at the time of revision.<sup>7,8</sup> One reported an alarming survival rate of 63% at ten years' follow-up,<sup>7</sup> and the other, using a biological reconstruction technique with impaction bone grafting, showed more promising results, with a ten-year survival rate of 87%.<sup>8</sup>

The aim of this study was to analyze the outcome of subsequent revision procedures in > 1,000 consecutive primary

THAs undertaken in patients aged < 50 years, all performed at our institution using a routine procedure with cemented components. We analyzed the outcome of the primary THA and focused on the outcome of the subsequent revisions and re-revisions. We also wished to report the incidence of excision arthroplasty, a Girdlestone procedure,<sup>9</sup> in these patients, as a measure of failure which seriously limits the mobility of the patient.

## Methods

This was a retrospective cohort study involving all patients, aged < 50 years, who underwent primary THA between 1 January 1988 and 31 December 2017 in our tertiary care institution (The Radboud University Medical Centre, Nijmegen, The Netherlands). Those patients in whom THA was undertaken for a primary or metastatic tumour were excluded.

A total of 1,049 primary THAs, performed in 860 patients, were included. Their mean age at the time of primary THA was 36.7 years (12 to 50), with 590 (56.2%) being female. During follow-up, 68 patients (92 THAs) died. These were included in the analyses, and censored at the time of death. A total of 114 patients (138 THAs) had not been reviewed in the outpatient department since 2015. Most of these were due to be updated in 2020, but due to the COVID-19 pandemic we had to postpone their review. However, follow-up data were included in the analyses and censored at the time of their most recent outpatient review.

Approval for this study was obtained from our local medical ethical committee. No formal informed consent is needed from the patients for this kind of study in the Netherlands.

All primary THAs were undertaken using the posterolateral approach, and cemented acetabular and femoral components. Acetabular defects are often encountered in these patients due to developmental dysplasia or trauma. Impaction bone

**Table I.** Patient characteristics of 1,049 primary total hip arthroplasties.

Characteristic	Value
Mean age, yrs (SD)	38.6 (9.3)
<b>Sex, n (%)</b>	
Male	459 (43.8)
Female	590 (56.2)
<b>ASA grade, n (%)</b>	
ASA I	395 (37.7)
ASA II	329 (31.4)
ASA III to IV	82 (7.8)
Missing	243 (23.2)
<b>Indication, n (%)</b>	
Primary OA	88 (8.4)
DDH	299 (28.5)
RA	72 (6.9)
AVN	288 (27.5)
Post-Perthes'	69 (6.6)
Post-traumatic OA	74 (7.1)
Other	159 (15.2)

ASA, American Society of Anesthesiologists; AVN, avascular necrosis; DDH, developmental dysplasia of the hip; OA, osteoarthritis; RA, rheumatoid arthritis; SD, standard deviation.

grafting was used for the reconstruction of these defects. The femoral head was used as autograft in primary THA. In some primary cases with larger defects, the autograft was combined with a fresh frozen femoral head allograft. In patients in whom the femoral head was not available for autograft, only allograft was used. In those with a segmental or medial wall defect of the acetabulum, a lateral rim or medial wall titanium mesh was used, in combination with grafting. The graft was morcellized with a rongeur or a bone mill to provide chips with a diameter of 0.7 to 1.0 cm, which were introduced using a metal impactor. The aim was to reconstruct the original centre of rotation by using the transverse ligament as a landmark. Antibiotic-loaded cement was pressurized into the acetabulum before implantation of the component (Figure 1). The femoral component was implanted using third-generation cementing techniques.

In subsequent revision procedures, after removal of the components, and taking microbiological cultures, bone defects were reconstructed using the same technique of acetabular impaction grafting and a cemented component. Impaction grafting was also used in patients with a femoral defect. In those undergoing revision for infection, a two-stage procedure was used. The techniques of impaction grafting have been extensively described.<sup>10–14</sup> This study was conducted and reported according to STROBE guidelines.<sup>15</sup>

**Statistical analysis.** The survival of the primary THA was recorded as the time between the primary procedure and the date of revision, the death of the patient, or the date of the most recent outpatient review. In patients with an excision arthroplasty, follow-up ended at the time of removal of the components. Using Kaplan-Meier analyses, we estimated survival including 95% confidence interval (CI) of all primary THAs with revision for any reason, and revision for aseptic loosening as the endpoints. We also estimated the survival of the acetabular and femoral components separately with the endpoint of revision for any reason. Survival was stratified for sex, age group (< 30,

**Table II.** Overview of the components which were used.

Acetabular	n
Contemporary flanged	582
De Puy Elite Plus LPW Cup	141
Contemporary hooded	134
Exeter rimfit	61
Muller	57
Exeter	48
Charnley/Ogee	13
Avantage	10
Missing	3
<b>Femoral</b>	
Exeter	890
Charnley	123
Muller	33
Missing	3

30 to 39, and 40 to 49 years), and different primary indications for THA. The rates of survival were reported, where possible, at ten, 20, and 25 years' follow-up.

We determined the survival of the subsequent revision procedures, calculated as the time between the revision and re-revision procedures, the death of the patient, or the date of the most recent outpatient visit. Survival of the revision procedures was reported at ten and 15 years' follow-up. The cumulative failure rates were also calculated.

All analyses were performed using R v. 3.5.1 (R Foundation for Statistical Computing, Austria), and significance was set at  $p < 0.05$ .

## Results

The most common primary diagnoses were developmental dysplasia ((DDH) n = 299) and avascular necrosis ((AVN) n = 288). The mean follow-up for all primary THAs was 8.7 years (2.0 to 31.5). Other characteristics of the patients are shown in Table I.

The most used acetabular component was the Exeter Contemporary flanged component (Stryker, UK) (n = 582); the most used femoral component was the Exeter (n = 890). The components which were used are shown in Table II.

Acetabular impaction grafting was used in 751 THAs (71.6%); of these, an autograft was used in 581, a combination of both autograft and allograft in 97, and only allograft in 73 THAs. Of all primary acetabular components, a rim mesh was used in 240 THAs, a medial mesh in 52, and a combination of both in 44.

A total of 138 revision procedures (13.2%) were performed involving any component for any reason. The mean age at time of the first revision was 48.2 years (23 to 72).

In 127 THAs, the acetabular component was revised; in 61 this was done in combination with revision of the femoral component. In 74 THAs, the indication for acetabular revision was aseptic loosening, and in 27 the indication was septic loosening (Table III).

Only the femoral component was revised in ten THAs. The indication for femoral revision was aseptic loosening in four, dislocation in one, and other reasons in five. One revision involved only a change of the femoral head, due to recurrent dislocation (Table III).

In four THAs (four patients), there was no reimplantation during the first revision due to infection, eventually resulting in a permanent Girdlestone arthroplasty. In all other patients

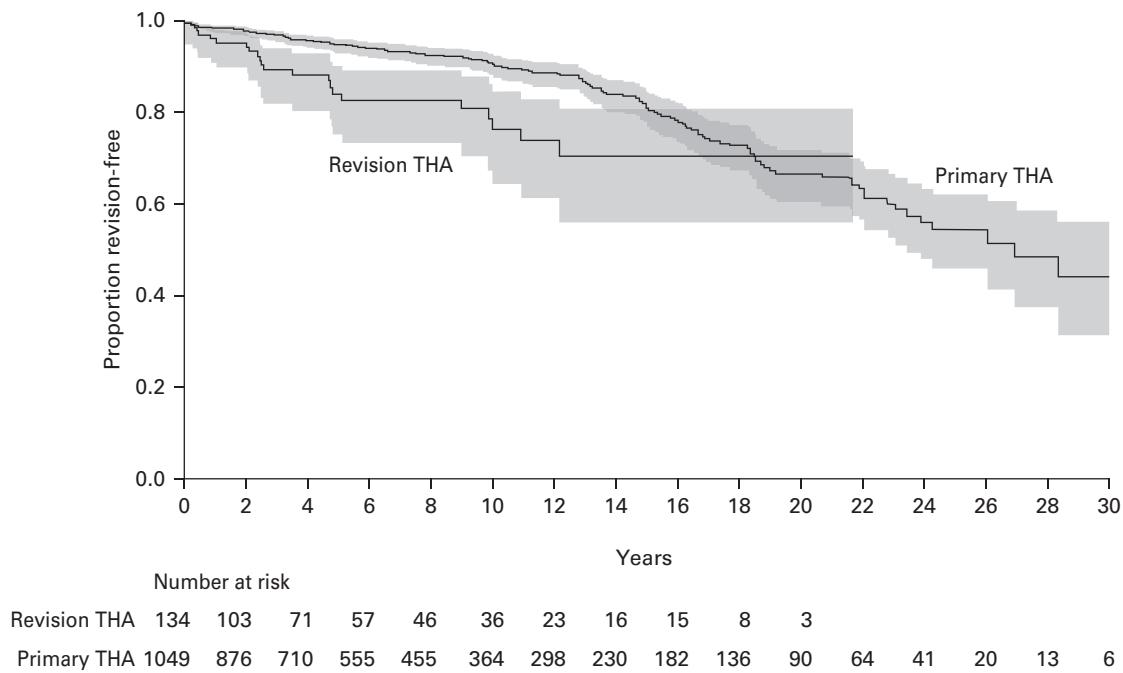


Fig. 2

Survival of 1,049 primary total hip arthroplasties (THAs) and 138 revision procedures with an endpoint of (re-)revision for any reason.

**Table III.** Characteristics of revisions and re-revisions.

Characteristic	Revisions (n = 138)	Re-revisions (n = 22)
Mean age, yrs	48.2	51.1
<b>Sex, n (%)</b>		
Male	55 (39.9)	10
Female	83 (60.1)	12
<b>Component, n</b>		
Acetabular	127	20
Femoral	71	10
Head	1	N/A
<b>Indication for revision, n</b>		
Aseptic loosening	78	4
Septic loosening	27	11
Dislocation	14	3
Wear	4	0
Other	12	4
Missing	3	0

N/A, not applicable; SD, standard deviation.

with septic loosening, a second-stage reimplantation procedure was undertaken.

Kaplan-Meier analysis showed a survival rate for all primary THAs with an endpoint of revision for any reason of 90.7% (95% CI 88.2 to 92.7) at ten years, 66.7% (95% CI 60.5 to 72.2) at 20 years, and 54.4% (95% CI 45.7 to 62.2) at 25 years' follow-up (Figure 2). The rates of survival for primary acetabular and femoral components separately, and survival rates with an endpoint of aseptic loosening, are shown in Table IV. Using competing risk analyses, we calculated the cumulative incidence of revision for any reason, with death

considered as a competing risk. The cumulative failure was 29.9% (95% CI 24.9 to 35.1) at 20 years' follow-up for all primary THAs, and after a revision THA was 27.3% (95% CI 17.1 to 38.6) at 15 years' follow-up.

A total of 253 cases (24.1%) were undertaken in patients aged < 30 years, 315 (30.0%) in those aged between 30 and 39 years, and 481 (45.9%) in those aged between 40 and 50 years. In patients aged < 30 years, survival for any reason was 90.3% (95% CI 84.4 to 94.1), 69.5% (95% CI 56.0 to 79.6), and 66.1% (95% CI 51.3 to 77.3) at ten, 20, and 25 years' follow-up, respectively. For those aged between 30 and 39 years, survival for any reason was 88.4% (95% CI 82.7 to 92.3), 68.6% (95% CI 57.4 to 77.4), and 56.4% (95% CI 39.8 to 70.0) at ten, 20, and 25 years' follow-up, respectively. For those aged between 40 and 49 years, survival was 92.4% (95% CI 88.9 to 94.9), 63.5% (95% CI 53.6 to 71.8), and 47.8% (95% CI 34.9 to 59.5) at ten, 20, and 25 years' follow-up, respectively (Table V).

The most common diagnosis at the time of the initial THA was DDH. Survival for patients with DDH was 89.9% (95% CI 84.5 to 93.5) and 83.7% (95% CI 75.6 to 89.3) at ten and 15 years' follow-up, respectively. For those undergoing THA for AVN, survival was 90.3% (95% CI 84.6 to 94.0) and 81.2 (95% CI 72.1 to 87.6) at ten and 15 years' follow-up, respectively. Survival rates of other indications for primary THA are shown in Table VI.

Of the 138 revision THAs, 22 required a re-revision. The mean age of the patients at re-revision surgery was 51.7 years (33 to 71). The mean follow-up for the revisions was 6.5 years (0.1 to 21.7). In 20 re-revisions, an acetabular re-revision was

**Table IV.** Survival rates of all primary total hip arthroplasties with endpoints of revision for any reason and revision for aseptic loosening (95% confidence intervals).

Reason	10-yr follow-up	20-yr follow-up	25-yr follow-up
Overall, any reason	90.7 (88.2 to 92.7)	66.7 (60.5 to 72.2)	54.4 (45.7 to 62.2)
Acetabular component, any reason	91.7 (89.3 to 93.6)	69.1 (63.0 to 74.4)	56.6 (47.9 to 64.5)
Femoral component, any reason	94.3 (92.2 to 95.8)	83.2 (78.1 to 87.3)	76.9 (69.0 to 83.0)
All aseptic	95.8 (93.7 to 97.2)	76.5 (70.2 to 81.6)	62.3 (52.5 to 70.7)
Acetabular component, aseptic	96.3 (94.3 to 97.6)	77.5 (71.3 to 82.5)	63.6 (53.8 to 71.8)
Femoral component, aseptic	97.9 (96.2 to 98.8)	90.5 (85.6 to 93.8)	83.6 (75.1 to 89.4)

**Table V.** Survival rates of all primary total hip arthroplasties by age group with an endpoint of revision for any reason (95% confidence interval).

KM all primary THAs (1,049)	10-yr follow-up	20-yr follow-up	25-yr follow-up
< 30 yrs (n = 253)	90.3 (84.4 to 94.1)	69.5 (56.0 to 79.6)	66.1 (51.3 to 77.3)
30 to 39 yrs (n = 315)	88.4 (82.7 to 92.3)	68.6 (57.4 to 77.4)	56.4 (39.8 to 70.0)
40 to 49 yrs (n = 481)	92.4 (88.9 to 94.9)	63.5 (53.6 to 71.8)	47.8 (34.9 to 59.5)

KM, Kaplan-Meier; THA, total hip arthroplasty.

undertaken, of which eight also involved a femoral re-revision. Aseptic acetabular loosening was the indication in four patients, and septic loosening in 11. All patients with septic loosening underwent a two-stage revision.

Only a femoral re-revision was undertaken in two patients. The indication was dislocation in one and fracture of the femoral component in the other.

Using Kaplan-Meier analysis, the survival of revision THA with the endpoint of re-revision for any reason was 78.5% (95% CI 67.3 to 86.2) at ten-year, and 70.3% (95% CI 56.1 to 80.7) at 15-year follow-up (Figure 2). For all revised acetabular components, survival was 78.7% (95% CI 66.8 to 86.8) and 69.7% (95% CI 54.3 to 80.7) at ten and 15 years' follow-up, respectively. For all revised femoral components, survival was 85.0% (95% CI 72.1 to 92.3) and 76.2% (95% CI 57.8 to 87.4) at ten and 15 years, respectively (Table VII).

Of the 22 re-revision procedures, seven required a second re-revision (Figure 3). The mean follow-up of all re-revision procedures was 3.5 years (0.2 to 11.7). Aseptic loosening was the indication in two, septic loosening in three, dislocation in one, and defined as 'other' in one. Both the acetabular and femoral components were changed in one second re-revision; in four, only the acetabular component was changed and it was not replaced in two, resulting in a permanent Girdlestone arthroplasty.

A Girdlestone arthroplasty was undertaken in four of 138 revision procedures at 0.1, 0.3, 0.9, and 4.6 years, respectively, after the primary procedure; all for sepsis. Components were reimplanted in all 22 re-revision procedures, after which these patients remained mobile.

A Girdlestone arthroplasty was undertaken in two of seven second re-revision procedures, at 8.9 and 6.7 years, respectively, after the primary procedure; both for sepsis. Thus, of the whole group of 1,049 primary THAs, in 860 patients, six (0.7%) had a Girdlestone arthroplasty, all for sepsis. No further surgery is planned in these patients. This incidence of Girdlestone arthroplasty, called the Girdlestone load, which includes the outcome of revisions and re-revisions, suggests that with our philosophy of treatment, the number of patients whose THA could not be revised during the study period was limited. Except for septic indications, all patients with a failed primary

**Table VI.** Survival rates of all primary total hip arthroplasties by diagnosis with an endpoint of revision for any reason (95% confidence interval).

Diagnosis	10-yr follow-up	15-yr follow-up
Primary OA	92.8 (81.3 to 97.3)	86.6 (65.5 to 95.2)
DDH	89.9 (84.5 to 93.5)	83.7 (75.6 to 89.3)
RA	88.6 (77.5 to 94.5)	79.2 (65.0 to 88.2)
AVN	90.3 (84.6 to 94.0)	81.2 (72.1 to 87.6)
Other	93.0 (86.1 to 96.5)	80.7 (68.8 to 88.4)
Post-Perthes'	94.7 (79.1 to 98.7)	89.4 (68.2 to 96.8)
Post-traumatic	88.0 (75.5 to 94.4)	78.6 (59.1 to 89.5)

AVN, avascular necrosis; DDH, developmental dysplasia of the hip; OA, osteoarthritis; RA, rheumatoid arthritis.

or revision procedure, underwent satisfactory reimplantation of components.

## Discussion

The aims of this study were to analyze the outcome and survival of both primary THAs and revision procedures, undertaken in a large cohort of patients aged < 50 years. We also determined the incidence of Girdlestone arthroplasty in these patients, as a measure of failure of THA. When performing THA in young patients, it is essential for the surgeon to have an idea of the outcome of the subsequent revision of the components, as revision procedures are inevitable in this group.

The findings provide an important update to the literature on revision arthroplasty of the hip in young patients. To our knowledge, this is the largest long-term follow-up study of a single-centre cohort of patients aged < 50 years, which includes the outcome of subsequent revisions. The importance of anticipating future revisions has to be emphasized. These patients are still young when they need a revision, with a mean age of 48 years at the time of revision surgery in our group. Even at the time of re-revision, they were still young, with a mean age of 52 years. In order to assess the true value of different techniques that are used worldwide for THA, it is not only important to report on the results of primary THA, but may be even more important to report the results of revisions and even re-revision procedures, as these outcomes will determine the long-term success of surgical treatment.

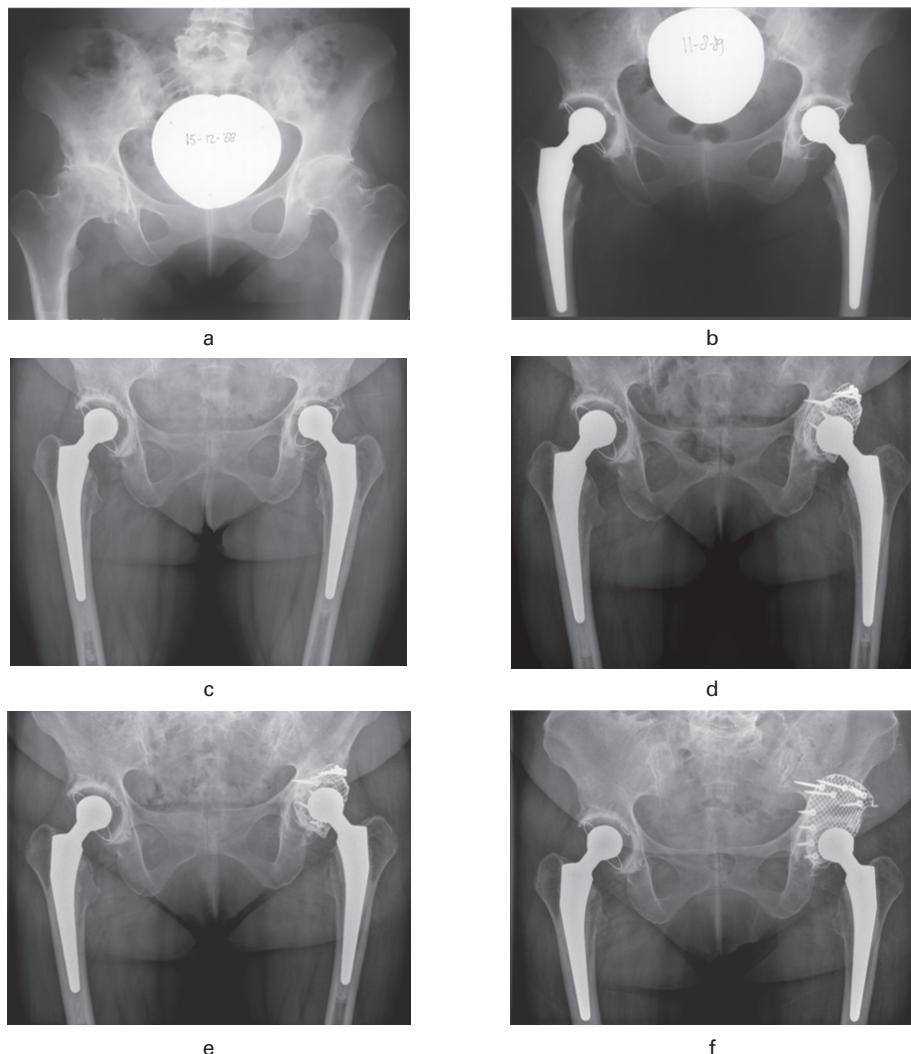


Fig. 3

Anteroposterior (AP) radiographs a) after a primary total hip arthroplasty in a female patient with bilateral osteoarthritis secondary to epiphyseal dysplasia. b) She underwent bilateral cemented total hip arthroplasty when aged 36 years, in 1989. c) Preoperative radiograph from 2015 showing aseptic acetabular loosening on the left with no signs of loosening on the right (after 25 years). d) Postoperatively after left-sided acetabular revision. e) Preoperative radiograph from 2019, with septic acetabular loosening on the left. f) Postoperative radiograph after two-stage re-revision of the acetabular component. The initial right sided arthroplasty remains satisfactory, albeit with some evident acetabular wear after > 30 years. The left hip also remained satisfactory at the most recent review.

**Table VII.** Survival rates of all revision total hip arthroplasties with the end-point of revision for any reason (95% confidence interval).

KM revisions (138)	5-yr follow-up	10-yr follow-up	15-yr follow-up
Overall	84.1 (75.0 to 90.1)	78.5 (67.3 to 86.2)	70.3 (56.1 to 80.7)
Acetabular component	85.1 (75.7 to 91.0)	78.7 (66.8 to 86.8)	69.7 (54.3 to 80.7)
Femoral component	85.0 (72.1 to 92.3)	85.0 (72.1 to 92.3)	76.2 (57.8 to 87.4)

KM, Kaplan-Meier.

Our method of using cemented THA combined with morcellized bone grafts in young patients to reconstruct bone loss if needed, leads to very acceptable long-term outcomes of primary THA and subsequent revisions. At 20 years' follow-up, the survival of primary THA was 66.7% (95% CI 60.5 to 72.2) with the endpoint of revision for any reason, with 90 patients still at risk at that time. The acetabular component showed promising survival of 69.1% (95% CI 63.0 to 74.4) at 20 years' follow-up with the endpoint of revision for any

reason, and a survival of 77.5% (95% CI 71.3 to 82.5) for the endpoint of aseptic loosening.

Our results of primary THA in young patients are similar when compared with long-term follow-up data for patients aged > 60 years at the time of primary THA, which is remarkable. A large systematic review and meta-analysis by Evans et al<sup>16</sup> showed a 25-year pooled survival of 57.9% (95% CI 57.1 to 58.7) in a group of patients with a mean age of 69 years, based on long-term follow-up data from the Australian and Finnish Registries.

Follow-up of the revision procedures in our study showed a survival of 70.3% (95% CI 56.1 to 80.7) at 15 years. The outcome of revision procedures in young patients has only been reported in a few studies,<sup>7,17-21</sup> and none also reported on the outcome of the primary THAs. Strömberg and Herberts<sup>20</sup> reported an overall survival of 76% after eight years' follow-up when using cemented revision THA. Lee et al<sup>7</sup> reported a survival after revision procedures of 63% at ten years' follow-up. Girard et al<sup>18</sup> reported 77 revision procedures in patients aged < 30 years, with survival at ten years' follow-up of 36%. Raut et al<sup>21</sup> reported a survival of 90% at six years' follow-up, for 87 cemented acetabular revision procedures in patients aged < 55 years. Our results of revision arthroplasty therefore compare very favourably with the available literature.

Importantly, we also determined the Girdlestone load in these patients, as the proportion of THAs which are no longer revisable. These patients generate high costs for society, in addition to the major impact of the permanent change to their lives, with limited mobility, a considerable leg length discrepancy, and often persistent pain.<sup>22</sup> Only six, of 1,049, THAs (0.7%) ended up as a Girdlestone arthroplasty. All these were required because of sepsis, further exposing the fact that an infected THA remains a devastating complication in young patients.

The most common indication for revision was aseptic loosening (n = 78, 56.5%), followed by infection (n = 27, 19.5%). However, the indication for 11 of 22 re-revision was infection, and only four revision procedures were re-revised for aseptic loosening. A similar result was found in an analysis of revision procedures in the Dutch Arthroplasty Register.<sup>23</sup> In a study on 1,037 revision procedures after primary THA in patients aged < 55 years, the rate of infection was 16% in the all revision procedures, which increased to 35% in all re-revision procedures. Thus, in the prevention of re-revision, the management of infection is of major importance.<sup>24</sup> Previous infection is not a contraindication to the use of impaction bone grafting in combination with a cemented implant. In our study, revisions for infection were all part of a two-stage procedure, when the reimplantation is undertaken in a controlled situation. Ammon and Stockley<sup>25</sup> showed that the use of impacted bone grafts with a cemented acetabular component in revision THAs in patients with extensive bone loss is a valuable option, provided that it is combined with systemic antibiotics. Cultures were taken at reimplantation in all patients, and in those with a positive culture appropriate systemic antibiotics were continued for 12 weeks. Rudelli et al<sup>26</sup> showed that impaction grafting when used in a one-stage revision for infection is an option: in 32 patients with septic loosening, they only reported two re-infections. We prefer a two-stage procedure for these revision cases. However, local antibiotics mixed with the bone grafts would be an option, also as part of a two-stage revision.

A strength of this study is that we have been able to monitor almost all the patients throughout the period of the study. A total of 114 patients had not visited the outpatient clinic since 2015, and might therefore be considered to be lost to follow-up. However, this was partly because of the COVID-19 pandemic. Follow-up for these patients ended at the time of their most recent visit, and we therefore did not miss any failure of the prosthesis or death in our analysis. All revisions, except for one,

were performed in our hospital. One acetabular revision was performed in a nearby hospital and we included the data of this patient until revision surgery.

Although the use of uncemented THA is popular in young patients, there is little evidence that these implants are superior to cemented implants.<sup>27</sup> A recent study from the National Joint Registry in the UK, reported that the outcome of uncemented THA was not superior to that of cemented primary THA.<sup>28</sup> Data on the outcome of revision procedures in young patients using uncemented components are limited and disappointing.<sup>7,18</sup>

In our study, the possible effect of competing risks had to be addressed.<sup>29,30</sup> Death might be a competing risk for our endpoint of interest: revision surgery. Using competing risk analyses, we assessed the cumulative incidence of revision for any reason, where death was considered a competing risk. We found a cumulative failure rate of 29.9% (95% CI 24.9 to 35.1) at 20 years' follow-up for all primary THAs, and the failure of revision THA was 27.3% (95% CI 17.1 to 38.6) at 15 years' follow-up. When comparing the cumulative failure rate with the Kaplan-Meier estimate of survival, the survival of both primary and revision THA in these patients might be underestimated when using Kaplan-Meier with an absolute difference of 3.4% and 2.4%, respectively.

As well as the possible effect of competing risks, there are other limitations that should be identified. All patients in our centre had a cemented THA, using the posterolateral approach. Although this provides homogeneity, the results might not be generalizable. However, the outcome of the subsequent revision undertaken using our technique can be used as a benchmark for other surgical approaches. Another critical consideration is the type of polyethylene which we used. Starting in 1988, all acetabular components which we used were made of traditional polyethylene. With the passage of time, we changed to a component made of a moderate crosslinked polyethylene (Duration; Stryker, UK), which we used until the end of the study. The results might have been better if highly crosslinked polyethylene had been used. We have recently started to use cemented acetabular components made of highly crosslinked polyethylene in young patients, which may reduce the number of future revisions for wear and aseptic loosening.<sup>31</sup>

In conclusion, this study provides an important update on the outcome of revision THA in young patients, filling a gap in the literature. The findings can be used as a benchmark for other surgical approaches and arthroplasties used in young patients. Both the patient and surgeon must realize that revision procedures are inevitable in patients who undergo primary THA at a young age. Therefore, data on the outcome of revision procedures are essential for both patient and surgeon in the decision-making process prior to a THA.

### Take home message

- The study of outcomes of total hip arthroplasty (THA) in young patients should also focus on the outcome of subsequent revision and re-revision procedures, as this will be a growing problem in young patients receiving primary THA.
- The use of cemented THA in young patients, combined with impaction bone grafting, results in very acceptable long-term outcomes of primary THA and their subsequent revisions.
- This study can be used as a benchmark for other techniques and prostheses used in young patients.

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## ■ THE KNEE SOCIETY

# Pain associated with cemented and uncemented long-stemmed tibial components in revision total knee arthroplasty

### Aims

Stemmed tibial components are frequently used in revision total knee arthroplasty (TKA). The purpose of this study was to evaluate patient satisfaction, overall pain, and diaphyseal tibial pain in patients who underwent revision TKA with cemented or uncemented stemmed tibial components.

### Methods

This is a retrospective cohort study involving 110 patients with revision TKA with cemented versus uncemented stemmed tibial components. Patients who underwent revision TKA with stemmed tibial components over a 15-year period at a single institution with at least two-year follow-up were assessed. Pain was evaluated through postal surveys. There were 63 patients with cemented tibial stems and 47 with uncemented stems. Radiographs and Knee Society Scores were used to evaluate for objective findings associated with pain or patient dissatisfaction. Postal surveys were analyzed using Fisher's exact test and the independent-samples *t*-test. Logistic regression was used to adjust for age, sex, and preoperative bone loss.

### Results

No statistically significant differences in stem length, operative side, or indications for revision were found between the two cohorts. Tibial pain at the end of the stem was present in 25.3% (16/63) of cemented stems and 25.5% (12/47) of uncemented stems ( $p = 1.000$ ); 74.6% (47/63) of cemented patients and 78.7% (37/47) of uncemented patients were satisfied following revision TKA ( $p = 0.657$ ).

### Conclusion

There were no differences in patient satisfaction, overall pain, and diaphyseal tibial pain in cemented and uncemented stemmed tibial components in revision TKA. Patient factors, rather than implant selection and surgical technique, likely play a large role in the presence of postoperative pain. Stemmed tibial components have been shown to be a possible source of pain in revision TKA. There is no difference in patient satisfaction or postoperative pain with cemented or uncemented stemmed tibial components in revision TKA.

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### Introduction

Total knee arthroplasty (TKA) is a commonly performed procedure in the USA and is anticipated to increase in requirement.<sup>1,2</sup> There has been a steady rise in revision TKA procedures in recent years. In 2014, one database query reported 72,100 revision TKAs performed annually with modelling projecting a 78% to 1.82-fold increase in these procedures from 2014 to 2030.<sup>2</sup> This increase is attributed to several factors including

a greater number of primary TKAs and primary TKA being performed in younger patients.<sup>1</sup> The most common indications for revision procedures include loosening, infection, instability and periprosthetic fracture.<sup>3</sup> Revision procedures are more likely to be associated with loss of distal femoral and proximal tibial bone stock, poorer soft tissue envelopes and lower patient satisfaction.<sup>2-10</sup>

The use of stemmed tibial components has been shown to improve patient outcomes in revision

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**Table I.** Patient demographic details and continuous variables.

Stem type	Variable	Mean (SD)	Median	Range	p-value*
<b>Cemented (n = 63)</b>	Age at time of revision, yrs	65.87 (8.87)	66.00	45.00 to 81.00	0.927
	Tibial stem diameter, mm	13.10 (1.92)	13.00	9.00 to 18.00	0.028
	Tibial stem length, mm	129.92 (33.41)	150.00	75.00 to 160.00	0.594
	% canal fill	73.52 (11.34)	72.73	46.54 to 95.71	< 0.001
<b>Uncemented (n = 47)</b>	Age at time of revision, yrs	66.02 (7.79)	67.00	51.00 to 82.00	0.927
	Tibial stem diameter, mm	14.13 (2.69)	67.00	10.00 to 22.00	0.028
	Tibial stem length	133.40 (33.41)	150.00	75.00 to 220.00	0.594
	% canal fill	90.81 (7.55)	90.48	71.00 to 100.00	< 0.001

\*Independent-samples t-test.

SD, standard deviation.

TKA by enhancing stability of the implant, allowing the surgeon to bypass structural metaphyseal defects, and reducing stresses at the bone-implant interface. These stresses are then distributed over the diaphyseal cortical bone.<sup>9-12</sup> Stemmed tibial components may be cemented or uncemented, although controversy exists regarding their respective use in revision settings. Several studies have compared cemented versus uncemented tibial stems by evaluating stem micromotion, re-revision rates, and functional outcomes of the patient, but have not found any statistically significant differences.<sup>4,6,9-11,13,14</sup>

Stem tip pain in the femur and thigh has been a well-documented phenomenon in total hip arthroplasty literature,<sup>6,8</sup> but fewer studies have evaluated diaphyseal tibial pain following revision TKA.<sup>15-18</sup> Diaphyseal tibial pain is thought to be clinically significant, because it has been associated with lower Knee Society clinical scores and a lower degree of patient satisfaction.<sup>15,19,20</sup> The aetiology of this pain is unknown. Biomechanical theories suggest stress risers at the tip of the stem may contribute to tibial pain or, conversely, excessive stress shielding resulting in bone resorption may also be a contributor.<sup>15,17</sup> Patient factors are also likely to play a role in its development, as those with lower preoperative Knee Society clinical scores are more likely to express diaphyseal tibial pain postoperatively.<sup>15</sup> The purpose of this retrospective cohort study was to evaluate overall pain levels, diaphyseal tibial pain, and patient satisfaction in revision TKA by comparing matched cohorts receiving long-stemmed uncemented or cemented tibial components.

## Methods

All patients who underwent revision TKA with uncemented or cemented tibial stems performed at a single institution by three fellowship-trained arthroplasty surgeons (KLG, BSK, CWH) during a 15-year period (2001 to 2016) were evaluated based on clinical records, subjective and objective radiological analysis, Knee Society Scores (KSSs),<sup>19,20</sup> and postal surveys. Ethical approval was granted for the study and all patients who participated provided informed consent. A database survey of revision knee current procedural terminology (CPT) codes identified 502 patients who had undergone revision TKA at our institution. Exclusion criteria included age under 18 years, isolated revisions of the femoral component or polyethylene insert exchanges, lack of preoperative or postoperative imaging, insufficient operative or implant records available for electronic chart review, revision procedures performed at elsewhere,

patients who were deceased at the time of survey administration, refusal to participate in the study, and failure to return the postal survey or respond to a telephoned follow-up questionnaire. A total of 502 unique revisions were identified; 244 were excluded for undergoing a revision procedure other than a revision TKA with a stemmed tibial component, 148 patients were deceased or lost to follow-up, leaving 110 included in the final study who engaged with the postal survey.

Indications for revision included aseptic loosening (38/110; 34.5%), infection (28/110; 25.5%), instability (19/110; 17.3%), arthrobiosis (12/110; 10.9%), component malrotation (9/110; 8.81%), and other causes such as periprosthetic fracture, extensor mechanism disruption, or metallosis (4/110; 3.63%).

Preoperative radiographs were evaluated for cavitary or segmental defects and categorized using the Anderson Orthopaedic Research Institute (AORI) classification by fellowship-trained arthroplasty surgeons (KLG, BSK, CWH).<sup>21</sup> Patients with types 2B and 3 tibial bone loss were considered to have significant bone loss for the purpose of our study. Postoperative radiographs were reviewed for any evidence of pedestal formation at the distal tip of the stem, radiolucent lines surrounding the stem, or evidence of periprosthetic fracture. Additional radiological analysis included calculation of the percentage of the tibial canal filled with the implant at its most distal extent before tapering to a smaller diameter, as well as the measurement of the diameter of the tibial stem at this location. All 63 cemented stems were monoblock titanium, while the uncemented cohort was 63.8% (30/47) splined stems with a tapered tip and 36.2% (17/47) that had a stress-relieving split shaft.

The mailed survey included a modification of the Knee Society pain subscore representing overall pain, questions specifically addressing the presence or absence of tibial pain before and after revision surgery, multiple choice questions regarding the specific location of tibial pain, and queries of overall satisfaction following the procedure (yes or no).<sup>19</sup> Implant records were reviewed to determine tibial stem length. Pre- and postoperative KSSs were used as an additional metric to assess pain and function.

**Statistical analysis.** Logistic regression was used to determine if the use of cemented or uncemented stems was predictive of overall postoperative pain or postoperative tibial pain after adjusting for age, sex, and bone loss. Odds ratios (ORs) with 95% confidence intervals (CIs) were used to show the results from the logistic regression models. Further statistical analysis was performed using Fisher's exact test to assess for

**Table II.** Comparison of categorical variables between groups from mailed survey.

Variable	Cemented stem, n (%)	Uncemented stem, n (%)	All, n (%)	p-value*
<b>Sex</b>				0.339
Male	33 (52.3)	20 (42.5)	53 (48.1)	
Female	30 (47.6)	27 (57.4)	57 (51.8)	
<b>Side</b>				0.447
Left	33 (52.3)	21 (44.6)	54 (49.0)	
Right	30 (47.6)	26 (55.3)	56 (50.9)	
<b>Q1: Satisfied with outcome of revision?</b>				0.657
Yes	47 (74.6)	37 (78.7)	84 (76.3)	
No	16 (25.3)	10 (21.2)	26 (23.6)	
<b>Q2: Presence of any pain AFTER revision?</b>				0.121
No	16 (25.3)	8 (17.0)	24 (21.8)	
Yes, mild/occasional	12 (19.0)	11 (23.4)	23 (20.9)	
Yes, mild/stairs only	6 (9.5)	1 (2.1)	7 (6.3)	
Yes, mild/walk/stairs	7 (11.1)	10 (21.2)	17 (15.4)	
Yes, moderate/occasional	9 (14.2)	4 (8.5)	13 (11.8)	
Yes, moderate/continuous	12 (19.0)	8 (17.0)	20 (18.1)	
Severe	1 (1.5)	5 (10.6)	6 (5.4)	
<b>Q3: Presence of tibial/shin pain BEFORE revision?</b>				0.518
Yes	19 (30.1)	11 (23.4)	30 (27.2)	
No	44 (69.8)	36 (76.5)	80 (72.7)	
<b>Q4: Presence of tibial/shin pain AFTER revision?</b>				1.000
Yes	16 (25.3)	12 (25.5)	28 (25.4)	
No	47 (74.6)	35 (74.4)	82 (74.5)	
<b>Q5: Presence of any pain BEFORE revision?</b>				0.696
Yes	58 (92.0)	45 (95.7)	103 (93.6)	
No	5 (7.9)	2 (4.2)	7 (6.3)	
<b>Q6: Knee or tibia on pain diagram preop? (K/T)</b>				0.226
Above knee (A)	3 (4.7)	6 (12.7)	9 (8.1)	
Knee (B&C)	34 (53.9)	26 (55.3)	60 (54.5)	
Shin (D)	4 (6.3)	N/A	4 (3.6)	
Above knee and knee (A-C)	5 (7.9)	6 (12.7)	11 (10.0)	
Knee and shin (B-D)	3 (4.7)	N/A	3 (2.7)	
Above knee, knee, shin (A-D)	8 (12.6)	7 (14.8)	15 (13.6)	
Above knee and shin (A&D)	1 (1.5)	N/A	1 (0.9)	
None	5 (7.9)	2 (4.2)	7 (6.3)	

Continued

**Table II.** Continued

Variable	Cemented stem, n (%)	Uncemented stem, n (%)	All, n (%)	p-value*
<b>Q7: Knee or tibia on pain diagram postop? (K/T)</b>				0.794
Above knee (A)	5 (7.9)	6 (12.7)	11 (10.0)	
Knee (B&C)	16 (25.3)	15 (31.9)	31 (28.1)	
Shin (D)	2 (3.1)	2 (4.2)	4 (3.6)	
Above knee and knee (A-C)	5 (7.9)	4 (8.5)	9 (8.1)	
Knee and shin (B-D)	2 (3.1)	N/A	2 (1.8)	
Above knee, knee, shin (A-D)	6 (9.5)	3 (6.3)	9 (8.1)	
Above knee and shin (A&D)	1 (1.5)	N/A	1 (0.9)	
None	26 (41.2)	17 (36.1)	43 (39.0)	
<b>Cavitory or segmental defects on preop radiograph tibia?</b>				0.177
Yes	3 (4.7)	1 (2.1)	4 (3.6)	
Yes (antibiotic spacer)	11 (17.4)	15 (31.9)	26 (23.6)	
No	26 (41.2)	12 (25.5)	38 (34.5)	
No (but radiolucency around tibial component)	23 (36.5)	19 (40.4)	42 (38.1)	
<b>Postop radiograph (pedestal formation distal tip, radiolucent lines around tibial component)</b>				0.020
Yes	1 (1.5)	7 (14.8)	8 (7.2)	
No	62 (98.4)	40 (85.1)	102 (92.7)	

\*Fisher's exact test.

associations between categorical patient characteristics, and the independent-samples *t*-test was used to compare continuous data between the two cohorts. A p-value < 0.05 was considered statistically significant. Descriptive statistics included counts and percentages for categorical data. Means, standard deviations (SDs), median, and minimums and maximums were used in the analysis of continuous data. SAS v. 9.4 (USA) was used to conduct the statistical analysis.

## Results

A total of 110 patients were included in the study, with 63 patients in the cemented stem group and 47 in the uncemented group. There were no significant differences in patient age, sex, stem length, operative side, or preoperative radiological findings between the groups (Table I). In all, 94 patients were found to be AORI Type 1 with 16 patients as AORI Type 2 on radiographs prior to revision. Routine clinical follow-up was performed at two weeks, then six weeks, three months, six months, one year, two years, and five years all with radiographs. There were no statistically significant differences

**Table III.** Preoperative logistic regression model for tibial pain (no = 80; yes = 30). No covariates were associated with tibial pain.

Predictor	OR (95% CI)	p-value
Cemented vs uncemented stem	1.415 (0.588 to 3.401)	0.438
Age at time of revision: 1 year increment	0.991 (0.941 to 1.043)	0.718
Sex: female vs male	1.346 (0.564 to 3.214)	0.503
Bone loss: yes vs no	0.771 (0.286 to 2.080)	0.608

CI, confidence interval; OR, odds ratio.

between indications for revision between the cemented and uncemented cohorts ( $p = 0.146$ , Fisher's exact test). There were statistically significant differences in the percentage of the tibial canal filled by the implant as well as the diameter of the implants in the cemented versus uncemented stems. The cemented group had a mean canal fill of 73.52% (SD 11.34%), while the uncemented group had a mean of 90.81% (SD 7.55%) ( $p < 0.001$ , independent-samples  $t$ -test). As expected, the uncemented group had larger diameter stems (mean 14.13 mm (SD 2.69)) than the cemented stems (mean 13.10 mm (SD 1.92);  $p = 0.028$ , independent-samples  $t$ -test). The uncemented group had a significantly higher number of abnormalities in postoperative radiographs (14.89%; 7/47) relative to the cemented group (1.58%, 1/63;  $p = 0.020$ , Fisher's exact test). These abnormalities were pedestal formation around the distal tip of the stem in uncemented stems (7/47) and radiolucent lines around the stem in the cemented group (1/63).

Tapered and split stem designs were used in the uncemented cohort. In all, seven patients underwent re-revision: three for periprosthetic joint infection, two for aseptic loosening, and two for instability. Re-revisions are unlikely to be either factors or confounders in this study, as their inclusion or exclusion did not alter the probability of diaphyseal pain ( $p = 0.121$ , Fisher's exact test).

There were no statistically significant differences in overall pain levels or diaphyseal tibial pain before or after revision TKA between cohorts. Survey questions were directed towards quantifying pain levels with different weight-bearing activities from stair climbing to ambulating on a flat surface. Prior to revision, 92.0% (58/63) of patients in the cemented group reported the presence of some pain; 30.1% (19/63) reported tibial pain specifically. In the uncemented cohort, 95.7% (45/47) reported the presence of some pain prior to revision, with 23.4% (11/47) noting pain in the tibia or shin ( $p = 0.518$ , Fisher's exact test). Following revision, 25.4% (16/63) of individuals in the cemented group reported diaphyseal pain compared to 25.5% (12/47) of individuals in the uncemented group ( $p = 1.000$ , Fisher's exact test); 83.0% (39/47) of patients in the uncemented group reported pain ranging from mild to severe, whereas 74.7% (47/63) of patients in the cemented group reported the presence of postoperative pain. This difference was not statistically significant ( $p = 0.121$ , Fisher's exact test). The cemented and uncemented groups reported 74.6% and 78.7% satisfaction with the revision surgery, respectively ( $p = 0.657$ , Fisher's exact test) (Table II). No patients with radiological findings about the stem reported diaphyseal tibial pain.

The KSS in 40 patients who had surgery before 2011 (when we began to use the new scoring system) gave a mean

**Table IV.** Postoperative logistic regression model for tibial pain (no = 82; yes = 28). No covariates were associated with tibial pain.

Predictor	OR (95% CI)	p-value
Cemented vs uncemented stem	0.970 (0.401 to 2.346)	0.947
Age at time of revision: 1 year increment	0.987 (0.937 to 1.041)	0.639
Sex: female vs male	1.333 (0.547 to 3.247)	0.527
Bone loss: yes vs no	0.641 (0.227 to 1.809)	0.401

CI, confidence interval; OR, odds ratio.

improvement of 31.75 points in the cemented cohort and 21.33 points in the uncemented cohort ( $p = 0.314$ , independent-samples  $t$ -test). Similarly, the KSS in 70 patients who had surgery after 2011 reported a mean improvement of 31.62 points in the cemented cohort and 21.53 points in the uncemented cohort ( $p = 0.434$ , independent-samples  $t$ -test). The scores obtained prior to 2011 could not be compared to the scores obtained after 2011 due to a change in the score guidelines which was not directly translatable.

A logistic regression model did not find any difference between the two methods of stem fixation with overall postoperative pain (OR 0.535, 95% CI 0.198 to 1.448;  $p = 0.221$ ) or postoperative diaphyseal tibial pain (OR 0.970, 95% CI 0.401 to 2.346;  $p = 0.947$ ) adjusting for age, sex, and bone loss. None of the covariates (age, sex, bone loss, or method of stem fixation) were associated with postoperative overall or diaphyseal tibial pain (Tables III and IV). There was insufficient power to determine a significant difference in diaphyseal pain in the cemented and uncemented cohorts. All eligible patients were included in the study. Cohorts of 400 patients each are needed to detect the difference in pain observed in our study with 80% power.

## Discussion

Our study identified no statistically significant differences in preoperative or postoperative diaphyseal tibial pain and overall pain in patients who underwent revision TKA with cemented or uncemented tibial stems. The authors expected to find significantly greater percent canal fill, stem diameter, and pedestal formation at the end of the tibial stem in the uncemented group due to required surgical technique and implant design. However, those radiological findings are unlikely to be the primary cause of overall or diaphyseal tibial pain in a revision TKA as we found that diaphyseal tibial pain exists in the presence of both cemented and uncemented tibial components. Factors other than stem fixation may play a larger role in postoperative pain and patient satisfaction.

The radiological findings of this study support previous results showing no association with diaphyseal tibial pain. Peters et al<sup>6</sup> found radiolucent lines were more prevalent adjacent to press-fit uncemented stems, but the difference did not correlate with clinical failure, radiological failure, or diaphyseal tibial pain. Gililland et al<sup>4</sup> found no difference in radiological loosening or failure between cemented and uncemented stems in a revision setting. Bertin et al<sup>22</sup> reported the majority of press-fit stems in their study developed pedestal formation at the stem tip along with cortical hypertrophy but found no difference in functional outcomes or re-revision rates.

Several studies have relied on patient surveys to quantify the intensity, duration, and functional sequelae of pain. Malviya et al<sup>7</sup> determined that one year was the optimal period to assess patient-reported outcome measures, such as pain levels and functional scores, after revision TKA. All patients involved in our study were surveyed at least one year after their revision, at a time when they should have achieved maximum pain relief and function. Similar to Barrack et al,<sup>15</sup> drawings were provided in the mailed surveys for patients to localize and characterize the intensity of their pain. The authors of the present study offered multiple-choice questions in order to better categorize and discriminate where patients experienced pain as opposed to free-hand drawings. The results in this study were similar to those found by Barrack's group; diaphyseal tibial pain was reported in both cemented and uncemented cohorts, but there was no statistically significant difference between the two groups.

Several studies have provided evidence that implant design and other biomechanical factors may play a role in diaphyseal tibial pain. Studies by Barrack et al,<sup>18</sup> Completo et al,<sup>16</sup> Kimpton et al,<sup>17</sup> and Glenn et al<sup>18</sup> evaluated diaphyseal tibial pain in association with differing stem designs, stem material, and stress concentrations at the stem tip. The authors found that differing designs and materials increase stress concentrations at the stem tip, but are not necessarily associated with increased diaphyseal tibial pain.

Biomechanical studies have suggested that pain may be caused by stress risers with press-fit stems but have not explained the diaphyseal tibial pain associated with cemented stems. While stress shielding and distal load transfer are common characteristics shared among cemented stems, they have not been consistently associated with diaphyseal tibial pain.<sup>23</sup>

Patient satisfaction is a clinically important outcome following TKA. Bourne et al<sup>24</sup> found that 19% of all patients were dissatisfied or neutral regarding their outcome after primary TKA. Our study found that 74.6% (47/63) of the cemented stem cohort and 78.7% (37/47) of the uncemented cohort were satisfied following their revision procedure ( $p = 0.657$ ). These findings were consistent with prior studies showing decreased satisfaction rates among patients undergoing revision procedures compared to primary TKA.<sup>25,26</sup>

Preoperative patient factors appeared to contribute to post-operative diaphyseal tibial pain. The number of patients who reported tibial pain prior to revision surgery was largely unchanged from the number of patients who reported tibial pain following the procedure. In the cemented cohort, 30.2% (19/63) of patients reported preoperative tibial/shin pain, whereas 23.4% (11/47) of patients in the uncemented group reported the same; 25.4% (16/63) in the cemented and 25.5% (12/47) in the uncemented group reported postoperative pain. This could be the result of recall bias or poor comprehension of the survey instructions. Additionally, the survey instructed patients to pick one location where the most pain was felt, and the majority of patients picked several. The medial and lateral joint lines of the knee were the most common locations for patients to report pain both preoperatively and postoperatively in both cohorts.

Petersen et al<sup>27</sup> evaluated the difference in pain, mobility, and quality of life, in patients who underwent primary TKA

and revision TKA. They found 47% of patients had severe chronic pain following a revision TKA, compared to 19% of patients who experienced chronic pain following a primary TKA. The authors suggested several factors could contribute to the difference in chronic pain seen in revision TKA including an increased number of patient comorbidities, possible centralization of pain, and patients who described greater than one location of pain. Lewis et al<sup>28</sup> further described predictors of persistent pain after TKA and found that pain catastrophizing, depression and anxiety, and pain at more than one location were strong predictors of chronic pain following surgery. In fact, those psychological factors were consistently associated with long-term pain while patient biomechanics, demographic details, and perioperative variables had limited influence on chronic pain. Given those findings, the surgeon's focus should be directed towards identifying and managing preoperative risk factors associated with chronic pain such as pain catastrophizing and widespread pain.

There were several limitations to this study. There is a risk for recall bias as this is a retrospective study and depended upon patients accurately describing their pre- and postoperative pain levels and intensity. Metaphyseal cones or sleeves were present in 16/110 (14.5%) cases, and there was no statistically significant difference in diaphyseal pain for either cohort. All metaphyseal sleeves or cones were used in the setting of previous periprosthetic joint infections. All metaphyseal implants were press-fit, while the stem was cemented distally and included in the cemented cohort. Additionally, this is the first study to include infection as an indication for revision TKA when evaluating diaphyseal tibial pain. This could be a possible confounding variable; however, there did not appear to be any association of diaphyseal tibial pain with infection observed in either cohort.

In conclusion, well-fixed revision TKAs with cemented or uncemented stems have a similar incidence of diaphyseal tibial pain. There are no statistically significant differences in overall pain, diaphyseal tibial pain, or patient satisfaction following revision TKA using cemented or uncemented tibial stems. Several biomechanical studies have suggested implant material and design may contribute to diaphyseal tibial pain by increasing stress risers at the stem tip in press-fit stems, but a paucity of literature exists evaluating similar biomechanics in cemented stems. The lack of consistent surgical and biomechanical factors contributing to diaphyseal tibial pain suggest that the cause is likely multifactorial. Patient factors likely play a more significant role in the aetiology of overall pain and diaphyseal tibial pain than previously thought. Further studies evaluating the preoperative identification and management of risk factors associated with chronic pain such as pain catastrophizing and widespread pain may provide greater insight into the subject.



#### Take home message

- Patient satisfaction is equal in patients with cemented and uncemented stems for revision total knee arthroplasty (TKA).
- Overall pain and diaphyseal tibial pain is equal in patients with cemented and uncemented stems for revision TKA.

## Twitter

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All patients consented to participate in this research study and the research was approved by the University of Nebraska Medical Center Institutional Review Board.

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## ■ WRIST & HAND

# Predictors for poor outcome for conservatively treated traumatic triangular fibrocartilage complex tears

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### Aims

The primary aim of this study was to assess if traumatic triangular fibrocartilage complex (TFCC) tears can be treated successfully with immobilization alone. Our secondary aims were to identify clinical factors that may predict a poor prognosis.

### Methods

This was a retrospective analysis of 89 wrists in 88 patients between January 2015 and January 2019. All patients were managed conservatively initially with either a short-arm or above-elbow custom-moulded thermoplastic splint for six weeks. Outcome measures recorded included a visual analogue scale for pain, Patient-Rated Wrist Evaluation, Disabilities of the Arm, Shoulder and Hand score, and the modified Mayo Wrist Score (MMWS). Patients were considered to have had a poor outcome if their final MMWS was less than 80 points, or if they required eventual surgical intervention. Univariate and logistic regression analyses were used to identify independent predictors for a poor outcome.

### Results

In total, 76% of wrists (42/55) treated with an above-elbow splint had a good outcome, compared to only 29% (10/34) with a short-arm splint ( $p < 0.001$ ). The presence of a complete foveal TFCC tear ( $p = 0.009$ ) and a dorsally subluxated distal radioulnar joint (DRUJ) ( $p = 0.032$ ) were significantly associated with a poor outcome on univariate analysis. Sex, age, energy of injury, hand dominance, manual occupation, ulnar variance, and a delay in initial treatment demonstrated no significant association. Multiple logistic regression revealed that short-arm immobilization ( $p < 0.001$ ) and DRUJ subluxation ( $p = 0.020$ ) were significant independent predictive factors of an eventual poor outcome.

### Conclusion

Nonoperative management of traumatic TFCC injuries with above-elbow immobilization is a viable treatment method, particularly in patients without DRUJ subluxation. Early surgery should be considered for patients with dorsal ulnar subluxation treated with short-arm splints to prevent prolonged morbidity.

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### Introduction

The triangular fibrocartilage complex (TFCC) connects the distal radius, the distal ulna, and the palmar aspect of the ulnar carpal bones. It is a ligamentocartilaginous structure composed of seven distinct parts: the articular disc, volar and dorsal radioulnar ligaments (RUL), ulnolunate and ulnotriquetral ligaments, extensor carpi ulnaris subsheath, and the ulnocarpal meniscoid.<sup>1,2</sup> The dorsal and volar radioulnar ligaments, which comprise deep and superficial attachments to the distal ulna, are

considered to be the primary stabilizers of the distal radioulnar joint (DRUJ).<sup>3</sup> Stabilization is achieved statically through a complex arrangement of tightly packed parallel collagen strands and wave-like fibres that resist tensile forces, and dynamically via a dense innervation of mixed sensory nerve endings that influence neuromuscular control by nociception and proprioception.<sup>1,2</sup>

The Palmer classification divides TFCC tears into traumatic (Class 1) and degenerative (Class 2).<sup>4</sup> Traumatic injuries to the TFCC may result in

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ulnar-sided wrist pain, reduced forearm rotation, and mechanical symptoms of ‘clicking’. On clinical examination, patients can present with a positive ulnar fovea sign, crepitus on forearm rotation, pain on the ulnocarpal stress test, and a positive ballottement test for DRUJ stability.<sup>5</sup>

TFCC injuries frequently respond to non-surgical management.<sup>6–9</sup> It is agreed that surgical intervention should be reserved for patients with specific ulnar-sided wrist pain not relieved by conservative measures, or with symptomatic instability of the DRUJ.<sup>6</sup> However, there is a paucity of evidence to guide clinicians on the best method of treating these injuries nonoperatively. Since the TFCC is primarily responsible for stability during forearm rotation, it seems logical that healing can be better achieved by minimizing this movement. Despite evidence that suggests above-elbow immobilization significantly decreases rotation compared to short-arm methods,<sup>10</sup> there has been no consensus or published guidance with regards to the most appropriate form of immobilization in these injuries.

In this study, our primary aim was to determine whether above- or below-elbow immobilization alone can be successful in treating patients following traumatic TFCC tears. Our secondary aim was to identify clinical factors that may predict a poor prognosis after nonoperative management of these injuries.

## Methods

This was a retrospective cohort study conducted in a national tertiary orthopaedic referral centre (Beijing Jishuitan Hospital, China). Ethical approval was obtained from the institutional ethical board prior to study commencement. The medical records of all patients who presented to the department of hand surgery with a traumatic TFCC injury between January 2015 and January 2019 were scrutinized.

The inclusion criterion was all patients diagnosed with a traumatic TFCC tear. A diagnosis was based clinically on a positive history of trauma; the presence of ulnar-sided wrist pain; pain on pronation-supination; a positive provocative test on physical examination (ulnocarpal stress test, DRUJ ballottement test, or the piano key test); and evidence of a TFCC tear on 3.0 T MRI.

Patients were excluded if there was a lack of 3.0 T MRI images available within three months of the index injury; had a central TFCC perforation only; did not receive a minimum of three months of conservative management; had concomitant pathologies of ulnar-sided pain in the ipsilateral wrist, including DRUJ osteoarthritis, extensor carpi ulnaris tendinitis/subluxation, carpal instability, or osteoarthritis; wrist fracture; wrist deformity such as malunion; wrist osteoarthritis; inflammatory arthritis; and neuromuscular disorders.

There were 149 wrists in 148 patients with a clinical diagnosis of traumatic TFCC tear in the study period. Of these, 60 patients did not meet the inclusion criteria, leaving a total of 89 wrists in 88 patients for the final analysis (Figure 1). These included 47 males and 42 females; 63 were right-sided and 26 were left-sided. The dominant arm was involved in 63 patients. The mean age was 31 years (15 to 51). There were 11 patients with occupations that involved manual work.

All patients were initially managed by consultant hand surgeons, who were specialists of skill levels II to IV in the classification system devised by Tang and Giddins.<sup>11</sup> Initial treatment consisted of immobilization of the involved wrist with either a short-arm or

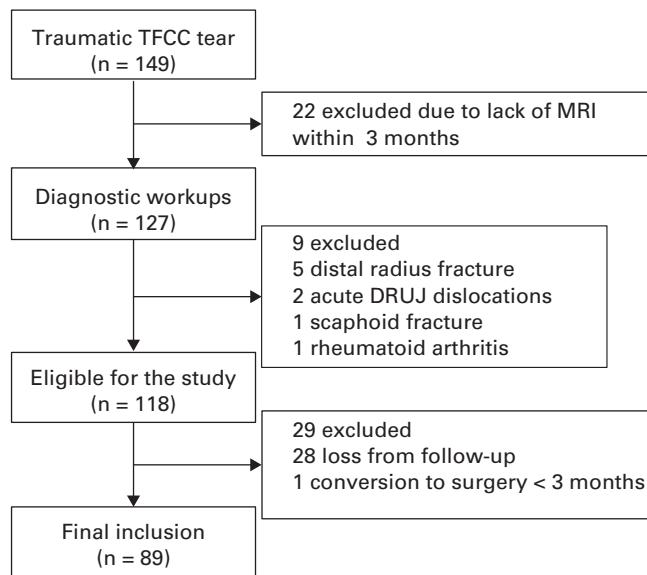


Fig. 1

A schematic diagram showing patient recruitment. DRUJ, distal radioulnar joint; TFCC, triangular fibrocartilage complex.

above-elbow metacarpophalangeal joint-free custom-moulded thermoplastic splint in semi-supination for six weeks, depending upon the preference of the treating surgeon. In our experience, patients tolerate immobilization in full supination poorly due to discomfort, and they often struggle with full pronation at the end of treatment. A semisupinated position is much better tolerated, caused less stiffness, and can still help to reduce dorsal ulnar subluxation if present.

Each patient had their demographic information (age, sex, dominant arm involvement, and occupation) recorded. The diagnostic investigations included a physical examination, standard orthogonal wrist radiographs, and 3.0 T MRI, which has high reliability for detecting TFCC tears.<sup>12</sup> The MRIs were reviewed by two independent musculoskeletal radiologists and a senior wrist surgeon (BL) to subclassify the type of TFCC tear, by scrutinizing the superficial and deep fibres of the radioulnar ligaments in three or more coronal slices at the ulnar fovea (a consensus was reached by discussion if there was disagreement in the initial independent classification). The tears were classified into two groups (Figure 2): those with complete avulsion of the deep fibres from the fovea, and those with tears of the superficial fibres only (foveal fibres intact) and/or partial deep fibre injuries.<sup>13</sup> We adapted Nakamura et al’s<sup>14</sup> technique to determine the presence of DRUJ subluxation from the MRI (Figure 3). Ulnar variance was measured on standard posteroanterior radiographs, with the forearm in neutral rotation, using the method of perpendiculars.<sup>15</sup> Ulnar plus variance was defined as a variance of 1 mm or more. The energy of injury was dichotomized into high or low depending on the causation. High-energy injuries were classified as falls from greater than two metres in height; sports injuries; or road traffic accidents. Low-energy injuries were defined as falls from less than two metres in height, or twisting injuries from activities of daily living. We recorded a delay in the initiation of treatment if eight weeks or longer elapsed between immobilization and the time of injury.

All patients were followed up at routine intervals for a minimum of 12 months, or until surgical intervention, by a single senior wrist

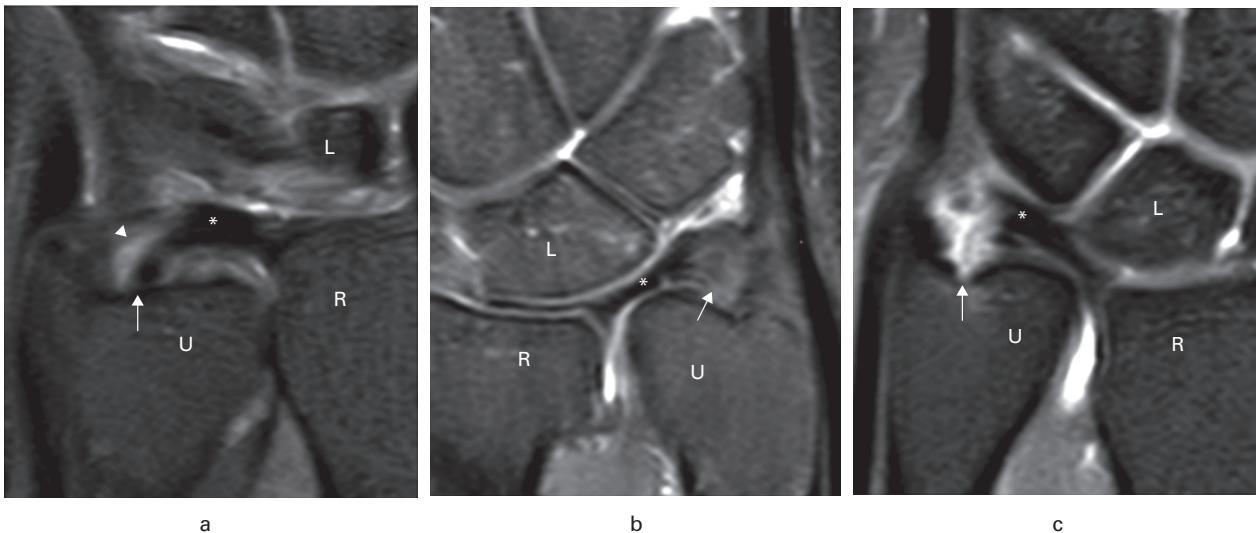


Fig. 2

MRI showing the different severities of triangular fibrocartilage complex tears. a) Superficial fibre injury (arrowhead) with foveal attachment intact (arrow). b) Partial deep fibre injury, shown as mixed signals in the course of the foveal fibres, with uninterrupted and normally aligned deep fibres in at least one coronal MRI slice. c) Complete deep fibre avulsion, shown by the discontinuity of the deep fibres in all coronal MRI slices. Asterisks represent the articular disc of the triangular fibrocartilage complex. L, lunate; R, radius; U, ulna.

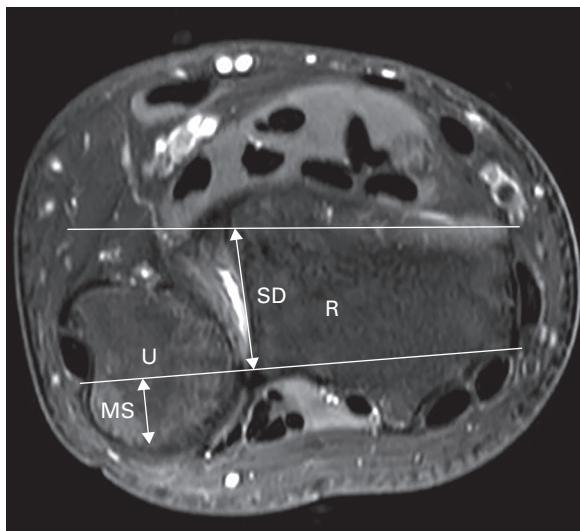


Fig. 3

MRI showing distal radioulnar joint subluxation. Subluxation is diagnosed when maximum width of the subluxated part of the ulna (MS) is greater than 25% of sigmoid notch diameter (SD).

surgeon (BL) of skill level IV.<sup>11</sup> Outcome measures recorded by a dedicated hand therapist included a visual analogue scale (VAS) for pain (0, no pain; 10, maximum pain), Patient-Rated Wrist Evaluation (PRWE) questionnaire,<sup>16</sup> Disabilities of the Arm, Shoulder and Hand (DASH) score,<sup>17</sup> and the Modified Mayo Wrist Score (MMWS).<sup>18</sup> One patient had injuries to both wrists sustained at different times, but had a full recovery before the second injury, therefore patient-rated outcomes could be collected for each wrist.

Patients were considered to have a poor outcome if they had a final MMWS score of less than 80 or were deemed suitable

**Table I.** Comparison of objective and subjective patient outcomes between patients with good and poor outcomes at final follow-up. All p-values were < 0.001, calculated using Mann-Whitney U test.

Median PROMs	Good outcome (IQR)	Poor outcome (IQR)
VAS	0 (0 to 1)	3 (2 to 4)
PRWE	5 (0 to 13.3)	19 (15 to 34)
DASH	2.3 (0 to 6.8)	18 (11 to 36)
MMWS	90 (85 to 96)	65 (50 to 65)

DASH, Disabilities of the Arm, Shoulder and Hand questionnaire; IQR, interquartile range; MMWS, Modified Mayo Wrist Score; PROMs, patient-rated outcome measures; PRWE, Patient-Rated Wrist Evaluation; VAS, visual analogue scale.

for conversion to surgical treatment. The MMWS was used as it is a point system based on four categories: pain, functional status, motion, and grip strength, with defined outcome ranges (excellent 90 to 100 points, good 80 to 89, fair 65 to 79, and poor less than 65).<sup>19</sup> Patients were offered surgery following assessment by the senior wrist surgeon (BL) if they were unresponsive to conservative interventions for at least three months and continued to suffer significant ongoing symptoms and disability that interfered with activities of daily living; and/or persistent DRUJ instability (diagnosed with a positive DRUJ ballottement test or positive piano key sign). All other patients were considered to have a good outcome.

**Statistical analysis.** Statistical analysis was performed using SPSS v. 26 (IBM, USA). The data were assessed for normality using the Shapiro-Wilk test, and reported using mean and range, or median and interquartile range (IQR) values as appropriate. Univariate analysis was performed using the Fisher's exact test for dichotomous variables. Comparisons between groups were tested using the independent-samples *t*-test or Mann-Whitney U test depending on data normality. Multivariate analysis was performed using forwards and backwards stepwise logistic regression of variables with a p-value < 0.1 on univariate analysis.

**Table II.** Univariate analysis of risk factors associated with a poor outcome.

Risk factor	Good outcome	Poor outcome	Relative risk (95% CI)	p-value
<b>Sex, n (%)</b>				
Female	23 (55)	19 (45)	1.18 (0.72 to 1.94)	0.526*
Male	29 (62)	18 (38)		
Mean age (range)	30.7 (15 to 43)	30.8 (17 to 51)		0.976†
<b>Side of injury, n (%)</b>				
Dominant	36 (57)	27 (43)	1.11 (0.63 to 1.96)	0.814*
Non-dominant	16 (62)	10 (38)		
<b>Occupation, n (%)</b>				
Manual worker	6 (55)	5 (45)	1.11 (0.55 to 2.23)	1.000*
Non-manual worker	46 (59)	32 (41)		
<b>Energy of injury, n (%)</b>				
High	17 (49)	18 (51)	1.46 (0.90 to 2.37)	0.186*
Low	35 (65)	19 (35)		
<b>Presentation, n (%)</b>				
Delayed immobilization ( $\geq 8$ wks)	17 (55)	14 (45)	1.14 (0.69 to 1.88)	0.656*
Early immobilization ( $< 8$ wks)	35 (60)	23 (40)		
<b>Immobilization, n (%)</b>				
Short-arm	10 (29)	24 (71)	2.99 (1.77 to 5.03)	< 0.001*
Long-arm	42 (76)	13 (24)		
<b>TFCC tear, n (%)</b>				
Complete foveal avulsion	6 (32)	13 (68)	2.00 (1.28 to 3.12)	0.009*
Incomplete foveal avulsion or foveal fibres intact	46 (66)	24 (34)		
<b>DRUJ alignment, n (%)</b>				
Dorsally subluxated	21 (47)	24 (53)	1.81 (1.06 to 3.07)	0.032*
Normal alignment	31 (70)	13 (30)		
<b>Ulnar variance, n (%)</b>				
Ulnar plus	24 (50)	24 (50)	1.58 (0.93 to 2.68)	0.090*
Ulnar neutral or negative	28 (68)	13 (32)		

\*Fisher's exact test.

†Independent-samples t-test.

CI, confidence interval; DRUJ, distal radioulnar joint; TFCC, triangular fibrocartilage complex.

Two tailed tests were used throughout and significance was defined at a p-value < 0.05.

## Results

The median follow-up duration was 24 months (IQR 10 to 34). Overall, there were 37 (42%) poor outcomes. These included 34 wrists who required surgery at a median duration of seven months post injury (IQR 6 to 13) and three wrists with MMWS scores of 55, 70, and 75 who did not seek surgical intervention. The follow-up duration was understandably shorter for those with a poor outcome (median eight months (IQR 6 to 13)) due to patients opting for surgery compared to those with a good outcome (median 32 months (IQR 27 to 38)). At final follow-up, as well as the MMWS, the VAS, PRWE, and DASH differed significantly between the two groups (Table I). The median difference was 3 in the VAS, 14 in the PRWE, 15.7 in the DASH, and 25 in the MMWS. From previously published studies, the minimal clinically important differences for the VAS is 3, PRWE is 14, and DASH is 10,<sup>20,21</sup> which indicated there were clinically meaningful disparities between those with good and poor outcomes.

**Predictive factors of poor outcome: univariate analysis.** On univariate analysis, there was a strong association between the method of immobilization and the eventual outcome ( $p < 0.001$ , Fisher's exact test; Table II). Patients treated with a short-arm splint had a threefold increase in the relative risk of a poor

outcome compared with above-elbow immobilization. Three out of four patients treated with an above-elbow splint had a good outcome, whereas more than two-thirds of those treated with a short-arm splint resulted in a poor outcome.

The presence of a complete foveal TFCC tear ( $p = 0.009$ , Fisher's exact test) and a dorsally subluxed DRUJ ( $p = 0.032$ , Fisher's exact test) were also significantly associated with a poor outcome. The presence of any of these risk factors conferred an almost doubling of the relative risk for a poor outcome compared with patients in which they were absent. However, when the results of patients treated with above-elbow immobilization were analyzed in isolation, those with a complete foveal tear or dorsally subluxed DRUJ had successful outcomes of 63% (5/8) and 74% (20/27) respectively.

Age, sex, dominant arm involvement, manual worker occupation, a delay in presentation of eight weeks or more, a higher causative energy of injury, and ulnar-positive variance were not significantly associated with an eventual poor outcome (Table II).

**Independent predictors of poor outcome: multivariate analysis.** Multiple regression models were performed because of suspected multicollinearity among the factors. Variables included in the multivariate analysis were immobilization method, presence of complete foveal avulsion, DRUJ alignment, and ulnar plus variance. The significant independent predictive factors for a poor outcome from this model were short-arm immobilization ( $p < 0.001$ ) and the presence of DRUJ subluxation ( $p = 0.020$ ; Table III). There were 18 wrists

**Table III.** Multiple logistic regression of significant predictors for a poor outcome.

Variable	Odds ratio (95% CI)	p-value
Short-arm immobilization	8.78 (3.14 to 24.60)	< 0.001
DRUJ subluxation	3.35 (1.2 to 9.27)	0.020

CI, confidence interval; DRUJ, distal radioulnar joint.

who exhibited both of these positive predictors in our series, of which 17 (94%) resulted in a poor outcome.

## Discussion

This study has shown that initial above-elbow immobilization of select patient groups with traumatic TFCC tears can be successful, regardless of DRUJ stability. Despite a good outcome in only 58% (52/89) of wrists overall, the proportion increased to over three-quarters (42/55) in those treated with an above-elbow splint. The presence of a complete foveal TFCC tear and a dorsally subluxed DRUJ were significantly associated with an eventual poor outcome. On multivariate analysis with the variables adjusted for one another to avoid confounding, the independent predictors for a poor outcome were short-arm splint use and the presence of dorsal DRUJ subluxation. A total of 79% (22/28) of wrists without DRUJ subluxation had a good outcome when treated with above-elbow immobilization alone.

Much attention has been paid to surgical TFCC repair techniques, but very few studies have concentrated on exploring the effectiveness of the nonoperative management of traumatic TFCC tears.<sup>7,8</sup> To date, only Lee et al<sup>7</sup> have sought to determine the natural course of patients with TFCC tears. In their series of 72 patients, only TFCC tears without DRUJ instability were included, and they found 30% of the patients achieved complete recovery following conservative treatment. However, they did not find any predictive factors associated with an incomplete recovery, which may be due to their study including both degenerate and traumatic tears with differing causative aetiologies and therefore differing healing potentials. Park et al<sup>8</sup> also reported that conservative treatment with a splint or cast is sufficient to avoid surgery in 57% of their cohort of 84 patients with a clinical diagnosis of TFCC injury without instability. However, they only instituted nonoperative management for four weeks and did not investigate for factors associated with successful conservative treatment.

It is known that the volar and dorsal radioulnar ligaments separately tighten in pronation and supination respectively,<sup>22,23</sup> and that above-elbow immobilization significantly reduces forearm rotation compared to short-arm methods.<sup>24</sup> When a tear occurs, the avulsed ligaments are still observed to remain in close proximity to the fovea ulnaris from post-injury MRIs. Therefore, we postulate that by inhibiting forearm rotation, tension and displacement of the avulsed ligaments are minimized, thus promoting healing of the TFCC. Our finding that above-elbow splint treatment is associated with a good outcome supports this theory in the nonoperative treatment of TFCC injuries.

DRUJ instability is frequently cited as an indication for primary operative fixation.<sup>25</sup> The diagnosis of clinical instability, however, can be challenging and has poor diagnostic sensitivity.<sup>26</sup> In the acute setting, it can be impractical and difficult to perform a formal DRUJ ballottement test and elicit accurate results in patients, who commonly present with severe pain. In the subacute setting, secondary stiffness

of the DRUJ after any form of immobilization may hide the true status of DRUJ stability during the physical examination. An MRI finding of a complete foveal TFCC tear is often a more accurate indicator of an unstable DRUJ,<sup>27</sup> and it was unsurprising to find an association between the severity of the TFCC lesion and the eventual outcome in this study. Similarly, dorsal subluxation of the DRUJ typically signifies a considerable disruption to the stabilizing mechanisms of the DRUJ. A dorsally subluxed ulnar head shifts the fovea ulnaris away from the avulsed TFCC deep fibres, thereby hindering the likelihood of healing without surgical intervention. Despite these associations, conservative treatment with an above-elbow splint can still be effective in the presence of these factors, with 63% (5/8) of wrists with a complete deep foveal avulsion and 74% (20/27) of wrists with DRUJ subluxation treated with above-elbow immobilization resulting in a good outcome.

Our results did not demonstrate a significant association between ulnar-plus variance and a poor outcome. This is surprising, as it is well known that lengthening the ulna relative to the radius increases the forces applied to the ulnocarpal joint,<sup>28</sup> and may represent a lack of adequate power from our modest sample size. However, it does corroborate similar findings from Lee et al<sup>7</sup> in their study of conservatively treated TFCC tears. We also did not observe an association between the energy of injury and a poor outcome. Due to the complex arrangement of structures at the wrist joint, not all energy sustained at the wrist is strictly proportionally passed on to the distal ulna in all mechanisms of trauma. It is possible that higher-energy injury mechanisms, such as a fall from height, may not always convey more energy to the TFCC when compared to a twisting rotational injury such as those commonly attributed to a so-called sprain. A delay in the initiation of immobilization in traumatic TFCC tears did not correlate with a poor outcome, which reflects our clinical experience. Often, we found delayed conservative treatment of traumatic DRUJ injuries presenting after two to three months can still yield good results. We postulate that in TFCC avulsions, particularly in incomplete tears, the ligaments may still remain close to their anatomical insertion site, therefore adequate healing could still occur despite a delay in initial immobilization.

There are a number of limitations to our study. It is subject to the usual limitations of a retrospective study, and the single-centre design is susceptible to selection bias. As a cohort study, patients were not randomized into the type of immobilization they received. It is therefore plausible that patients with milder clinical presentations may have had a higher likelihood of being prescribed short-arm splints and those with more severe injuries given above-elbow splints. Despite this potential bias, our finding of a significant difference in the outcome success between the immobilization methods should reinforce the message that an above elbow-splint should be offered in such injuries. There was a large patient dropout rate, although this was consistent with other similarly sized studies for this rare clinical condition.<sup>7</sup> Patients who were lost to follow-up were also more likely to have had a good outcome, as in our experience those with a poor outcome would be less willing to miss follow-up if they were continued to be functionally impaired. Therefore, the percentage of poor outcomes found in this series may in fact be an over-representation of the true incidence. Patients with a poor outcome had a shorter mean follow-up duration than those with a good outcome. Lee et al<sup>7</sup> however, demonstrated that symptom improvement plateaued between six and 12 months

following non-surgical management of TFCC tears, which would imply the difference in follow-up in this study would not represent a significant confounding factor. In all studies, there is a risk of intra- and interobserver variability. We have tried to minimize the bias from these factors by employing two musculoskeletal radiologists and a senior author to reach a consensus decision in the MRI classifications, and a single senior wrist specialist (BL) for post-treatment assessment and decision-making for surgery.

In conclusion, nonoperative management of traumatic TFCC injuries by above-elbow immobilization can be a useful treatment method for patients without DRUJ subluxation. In our institution, we now recommend that all patients without a subluxed ulna are immobilized in an above-elbow splint for a minimum of six weeks, and to only consider surgery if symptoms persist for three months or longer. Early surgery should only be considered for patients with dorsal subluxation treated with short-arm splints to prevent prolonged morbidity, as the likelihood of a good outcome was predictably low.



### Take home message

- Traumatic triangular fibrocartilage complex injuries without distal radioulnar joint subluxation can be successfully treated with above-elbow immobilization alone.
- Early surgery should be considered for patients with dorsal ulna subluxation treated with short-arm splints to prevent prolonged morbidity.

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J-Y. Xiao: Researched literature and conceptualized the study, Collected the data, Drafted, reviewed, and edited the manuscript.  
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L. Li: Helped to analyze and interpret the data, Reviewed and edited the manuscript.  
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In Inflammation, Injury, Wound, Osteoarthritis and Cellulitis

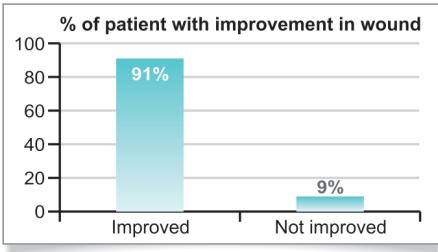
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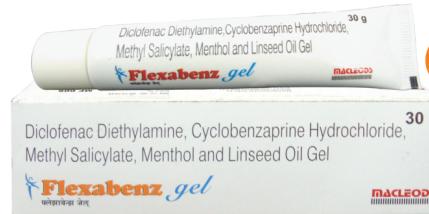


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