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Title

The incidence and temporal trends of dislocation following the use of constrained acetabular components and dual mobility implants in primary total hip replacements: a systematic review and meta-analysis of longitudinal observational studies
Abstract

Background

Dislocation after a primary total hip replacement (pTHR) remains a common cause of treatment failure. Constrained acetabular components (CACs) and dual mobility implants (DMIs) may mitigate this in patients at high risk of dislocation or with significant intra-operative instability. This meta-analysis evaluated the incidence and temporal trends of dislocation following implantation with CACs and DMIs in pTHR.

Methods

Longitudinal studies reporting dislocation following the use of CACs or DMIs in pTHR were sought from MEDLINE and EMBASE to September 2020. Secondary outcomes included revision surgery for dislocation and all causes.

Results

46 studies (three CAC; 43 DMI) comprising 582 CACs and 18,748 DMIs were included. The pooled incidence of dislocation was 1.08% (95% CI:0.00,3.72) (range 0.27-2.60%) over a weighted mean follow-up of 4.1 years for CACs, compared with 0.25% (95% CI:0.08,0.46) (range 0.00-4.72%) over 6.2 years for DMIs. For DMIs, there was a temporal decline in dislocations from the 1980s onwards, and dislocation rates remained low (<1%) until 15 years post-operatively. There were insufficient data for similar analysis of CACs. All studies were at high risk of bias. The incidence of revision for dislocation after CACs was 0.3% versus 0.1% for DMIs, and the incidence of revision for all causes after CACs was 4.8% versus 2.7% for DMIs.

Conclusion
DMIs demonstrated a lower incidence of dislocation compared to CACs; however, there was a relative absence of CACs used in the context of pTHR in the literature. Temporal trends in dislocation have improved over time for DMIs.
Keywords

Arthroplasty, Replacement, Hip

Hip Dislocation

Constrained Acetabular Component

Dual Mobility Implant

Systematic Review

Meta-Analysis
Introduction

Dislocation after primary total hip replacement (pTHR) remains a common cause of failure [1]. A recent meta-analysis of 4.6 million THRs across 125 unique studies found the incidence of dislocation to range from 0.1% to 16.1%, with a pooled incidence of 2.1% [2]. The sequelae of dislocation include severe pain, restriction of mobility, recurrent dislocation, and reduced quality of life [3]. 60% of dislocations occur early and in the first three months [4]. Higher rates of dislocation have been identified in patients with osteonecrosis, femoral neck fractures, hip dysplasia, neuromuscular disorders, abductor insufficiency, and cognitive impairment [5, 6]. Other patient factors include female sex, advanced age, and increased body habitus [7, 8]. Surgical factors include implant malpositioning, loosening, impingement (implant or bony), small head-neck ratios, inadequate soft tissue tension, the surgical approach and lower surgeon experience [9-11].

National Joint Registry (NJR) data in the United Kingdom (UK) identified dislocation as the third commonest indication for revision following a pTHR historically (after aseptic loosening and pain), and second commonest in the past five years (after aseptic loosening) [12]. Two groups of implants that seek to mitigate this burden are constrained acetabular components (CACs) and dual mobility implants (DMIs).

CACs resist dislocation by locking the femoral head captive within the acetabular component [13, 14]. The circumference of the polyethylene (PE) liner extends beyond the hemisphere of the acetabular shell/cup to achieve this; therefore, at the point of impingement or when the head would start to lift out of the cup, greater force is required to lever out the femoral head [15]. Common indications include recurrent dislocation, multidirectional intra-operative instability, abductor insufficiency, and neuromuscular disability (such as Parkinson’s disease and cerebral palsy) [7, 14]. The increased stability offered by these implants is at the expense of reduced range of motion, increased wear, and increased risk of component failure [7]. Acetabular screws are often required to prevent
avulsion of CACs before osseointegration has occurred. These implants are commonly reserved to treat instability that cannot be managed by other means [9].

DMIs consist of a small femoral head held captive yet mobile within the PE liner, which itself articulates with a highly polished metallic acetabular shell, combining the concepts of large diameter heads and low friction arthroplasty [16]. Implants may be cemented or uncemented. There are two main articulations: a small articulation between the head and the PE liner, and a large articulation between the polyethylene head and the acetabular shell [17]. When functioning as designed, most movement occurs at the small articulation; however, over time, stiffness can occur at this interface. Movement of the large articulation typically occurs when the stem’s neck comes into contact with the PE liner. Wear of the neck–PE contact area (the third articulation) can lead to intra-prosthetic dislocation (IPD) [18]. The increased stability is at the expense of increased wear. Their indications and contraindications are very similar to that of CACs.

To our knowledge, no existing literature has directly evaluated the incidence of dislocation following implantation of these prosthesis. The primary aim of this study is to systematically review and meta-analyse the literature to assess the incidence and temporal trends of dislocation after implantation of CACs and DMIs in patients with pTHRs.
Material and Methods

Data sources and search strategy

The review was registered *a priori* in the PROSPERO prospective register of systematic reviews (ID: CRD42020207351) and conducted according to a pre-defined protocol and in line with PRISMA guidelines. We searched for observational longitudinal study designs which reported on the incidence of dislocation in adults following pTHR that utilised CACs or DMIs. We systematically searched the databases of MEDLINE and EMBASE from inception to 03 September 2020. The computer-based searches used a combination of free and MeSH search terms and keywords related to the population (e.g., “total hip replacement”), and intervention (e.g., “constrained liner,” “dual mobility”). There were no restrictions on language. We used a combined search strategy for CACs and DMIs. The search was complemented by manually screening reference lists of retrieved articles and utilising the “Cited Reference Search” function in Web of Science to obtain additional studies missed by the search strategy. Any previously published systematic reviews and meta-analyses were screened for studies that met our eligibility criteria. The detailed search strategy is provided in Appendix 1.

Eligibility criteria

We included observational longitudinal studies that reported on the incidence of dislocation after pTHR where CACs or DMIs had been implanted in adults. The primary outcome was the incidence of dislocation. Secondary outcomes included the incidence of revision surgery for dislocation and the incidence of revision surgery for all causes.

We selected studies that represented the general population and therefore excluded articles that studied highly selective populations (e.g., only neck of femur fractures, or only neuromuscular disorders). We excluded studies that focussed on implantation in rTHR, and studies that did not segregate pTHRs from rTHRs. We excluded resurfacing arthroplasty, hemiarthroplasty, arthrodesis,
and cadaveric or animal studies. Study protocols, editorials, technical tips, and case reports were also excluded.

**Study selection and data extraction**

After completing the searches, results were imported into Rayyan [19], an online bibliographic tool. One reviewer (RLD) removed duplicates and screened the titles and abstracts to achieve a list of potentially relevant articles. Full-text screening of these articles was performed independently by one reviewer (RLD) against pre-defined eligibility criteria and verified by three reviewers (HJ, SF, MFS). Any discrepancies regarding article eligibility were discussed, and consensus was achieved through a senior author (SKK). One reviewer (RLD) independently conducted risk of bias assessments using a standardised data collection form. Three reviewers (HJ, SF, MFS) independently repeated the process to verify the data. A data extraction table was designed and piloted. Data were extracted on the lead author, year of publication, geographical location, study design, database type, dates (years) of interventions, number of participants, mean age, percentage of males, mean body mass index (BMI), mean American Society of Anesthesiologists [20] physical status classification score, intervention (CACs or DMIs), indications, arthroplasty type, duration of follow-up, outcome measures, number of hips/patients, and number of events (dislocation, revision for dislocation, revision for all causes). We also extracted data on relevant study characteristics to assess the risk of bias. For multiple publications involving the same cohort, the most up-to-date or comprehensive study was included. Authors were contacted to provide further information if data were missing.

**Risk of bias assessment**

The risk of bias within individual observational studies was assessed using the Cochrane Risk of Bias in Non-randomised Studies – of Interventions (ROBINS-I) tool, a validated tool for assessing the risk of bias in the results of non-randomised studies [21]. This tool assesses the risk of bias for confounding,
participant selection, classification of interventions, deviations from intended interventions, missing
data, outcome measurements and selective reporting. Risk is quantified in each domain as low,
moderate, serious or critical risk, then an overall judgement of the risk of bias is calculated for each
study.

Statistical analysis

Outcome data were pooled, and the incidence of dislocation (estimated from the number of dislocation
outcomes within the period of follow-up as a proportion of the total number of THRs as reported)
with 95% confidence intervals (CIs) was used as the summary measure. Given that the data was binary
with low rates, the Freeman-Tukey variance stabilising double arcsine transformation [22] was used in
calculating the rates. Temporal trends in incidence were evaluated using the median year of prosthesis
implantation/data collection reported by studies. Meta-regression analysis was used to assess
associations between incidence rates and median year of prosthesis implantation/data collection.
Random-effects models by DerSimonian and Laird, which considers heterogeneity both within and
between studies, were used to combine incidence estimates [23]. We estimated 95% prediction
intervals to determine the degree of heterogeneity, as they provide a range in which the underlying
true effects of future studies will lie with 95% certainty [24, 25]. We conducted stratified analyses and
random-effects meta-regression to assess several pre-defined study level characteristics (study size,
median year of data collection (1980s, 1990s, 2000 to 2009, and >2010), geographic origin (United
States, Europe, rest of the world) which could explain heterogeneity between the studies [26]. Effect
estimates for individual and pooled studies are summarised in forest plots, and heterogeneity was
assessed using the $I^2$ statistic to quantify inconsistency. To assess the potential for small-study effects or
publication bias, we conducted Egger’s regression symmetry test [27]. All statistical analyses were
performed using Stata version MP 16 (Stata Corp 2019, College Station, Texas, USA).
Results

Study identification and selection

Our search strategy identified 574 potentially relevant citations. This reduced to 426 after duplicates were removed. After screening titles and abstracts, 98 full-text articles remained for further evaluation. A further 55 were obtained by manually screening reference lists of retrieved articles and utilising the “Cited Reference Search” function in Web of Science. After full-text evaluation, 42 citations (46 studies) were eligible for inclusion in this meta-analysis. A PRISMA flow diagram for the study selection process is provided in Figure 1.

Figure 1. PRISMA flow diagram

Study characteristics

Four citations provided two sets of data each [28-31], and all other citations provided single datasets. A full list of eligible citations is provided in Appendix 2. The incidence of CAC dislocation was reported in three studies, and the incidence of DMI dislocation in 43 studies. 582 CACs were included (range 55-373) with follow-up ranging from 3.3-6.0 years. 18,748 DMIs were included (range 20-3,038) with follow-up ranging from 1.2-25.3 years. All citations provided observational data: 36 were retrospective and six were prospective. 35 citations were from Europe, six from North America and one from Asia. 57% of citations were from France. 36 citations were from institutional databases and six from national joint registries. Table 1 provides the characteristics of the included studies.

Table 1. Characteristics of included studies

Risk of bias
According to the ROBINS-I risk of bias tool, 42 citations displayed serious risk of bias, and two demonstrated critical risk of bias. The risk of bias assessments for individual studies is provided in Appendix 3.

Publication bias

Citations in this meta-analysis are of increased risk of publication bias, given the tendency for literature with significant results to be published (i.e., if dislocation rates are much lower or much higher than expected). Using Egger’s regression test, there was no evidence of publication bias among studies of CACs (p=0.512) or DMIs (p=0.403).

Primary outcomes

Incidence of dislocation – primary CACs

Across three studies of CACs, the incidence of dislocation over a weighted mean follow-up of 4.1 years ranged from 0.27-2.60%. The pooled incidence was 1.08% (95% CI: 0.00,3.72) (Figure 2). The 95% prediction interval for the summary incidence was 0.00-74.22%. There were insufficient data points to calculate the pooled incidence of dislocation at specific average follow-up periods, or temporal trends in dislocation rates. Meta-regression analysis was also not possible.

Figure 2. Incidence of dislocation after pTHR using CACs

Incidence of dislocation – primary DMIs

Across 43 studies of DMIs, the incidence of dislocation over a weighted mean follow-up of 6.2 years ranged from 0.00-4.72%. The pooled incidence was 0.25% (95% CI: 0.08,0.46) (Figure 3). The 95% prediction interval for the summary incidence was 0.00-1.72%. The pooled incidence of dislocation at specific average follow-up periods across 25 years of follow-up is displayed in Figure 4. Based on the
median year of data collection, the pooled incidence of dislocation was 1.16% (95% CI: 0.02,3.46) in the 1980s, 0.00% (95% CI: 0.00,1.88) in the 1990s, 0.06% (95% CI: 0.00,0.22) in 2000-2009, and 0.28% (95% CI: 0.04,0.67) in 2010 and beyond (Figure 5). In meta-regression analysis, there was no association between the incidence of dislocation and the median year of data collection (p=0.74) (Figure 6).

Figure 3. Incidence of dislocation after pTHR using DMIs

Figure 4. Incidence of dislocation after pTHR using DMIs at specific average follow-up periods

Figure 5. Temporal trends in dislocation after pTHR using DMIs

Figure 6. Meta-regression of dislocation after pTHR using DMIs

Secondary outcomes

Incidence of revision surgery for dislocation – primary CACs

Across three studies of CACs, the incidence of revision surgery for dislocation over a weighted mean follow-up of 4.1 years ranged from 0.27-1.82%. The pooled incidence was 0.28% (95% CI: 0.00,1.07) (Supplementary Material 1 – Figure A).

Incidence of revision surgery for dislocation – primary DMIs

Across 42 studies of DMIs, the incidence of revision surgery for dislocation over a weighted mean follow-up of 6.2 years ranged from 0.00-4.72%. The pooled incidence was 0.08% (95% CI: 0.01,0.21) (Supplementary Material 1 – Figure B). The pooled incidence of revision surgery for dislocation at specific average follow-up periods across 25 years of follow-up is provided in Supplementary Material 1 – Figure C. Based on the median year of data collection, the pooled incidence of revision surgery for
dislocation was 1.16% (95% CI: 0.02,3.46) in the 1980s, 0.00% (95% CI: 0.00,1.88) in the 1990s, 0.00% (95% CI: 0.00,0.01) in 2000-2009, and 0.22% (95% CI: 0.01,0.59) in 2010 and beyond (Supplementary Material 1 – Figure D). In meta-regression analysis, there was no association between the incidence of revision surgery for dislocation and the median year of data collection (p=0.82) (Supplementary Material 1 – Figure E).

*Incidence of revision surgery for all causes – primary CACs*

Across three studies of CACs, the incidence of revision surgery for any cause over a weighted mean follow-up of 4.1 years ranged from 3.25-5.63%. The pooled incidence was 4.76% (95% CI: 3.10,6.71) (Supplementary Material 2 – Figure F).

*Incidence of revision surgery for all causes – primary DMIs*

Across 39 studies of DMIs, the incidence of revision surgery for any cause over a weighted mean follow-up of 6.2 years ranged from 0.00-21.23%. The pooled incidence was 2.66% (95% CI: 1.83,3.62) (Supplementary Material 2 – Figure G). The pooled incidence of revision surgery for any cause at specific average follow-up periods across 25 years of follow-up is provided in Supplementary Material 2 – Figure H. Based on the median year of data collection, the pooled incidence of revision surgery for any cause was 12.37% (95% CI: 6.24,20.16) in the 1980s, 2.00% (95% CI: 0.78,5.03) in the 1990s, 2.17% (95% CI: 1.39,3.10) in 2000-2009, and 1.43% (95% CI: 0.79,2.21) in 2010 and beyond (Supplementary Material 2 – Figure I). In meta-regression analysis, there was a significant association between the incidence of revision surgery for any cause and the median year of data collection (p=0.005) (Supplementary Material 2 – Figure J).
Discussion

Key findings

Over a mean weighted follow-up period of 4 years, the incidence of dislocation following a pTHR utilising CACs ranged from 0.3-2.6% across individual studies, with a pooled incidence of 1.1%. For pTHR utilising DMIs, the incidence of dislocation ranged from 0.0-4.7% across individual studies, with a pooled incidence of 0.3% over 6 years. For DMIs, there appeared to be a temporal decline in dislocation rates from the 1980s onwards, and dislocation rates generally remained low (<1%) until 15 years. Similar analysis of CACs was not possible due to insufficient data points.

Comparison to existing work

Our literature review failed to yield any previous systematic reviews that have assessed outcomes following the use of CACs in pTHR. One study reviewed CACs in the context of any THR (primary, revision, re-revision) and reported the incidence of dislocation and/or failure rate of 11.4% (95% CI: 10.3,21.6) over a mean 4.3 years (range 0.8-20 years) [15]. Data on the use of CACs in pTHR is sparse, reducing the certainty of the estimates generated.

Comparatively, we identified three systematic reviews of DMIs used in pTHR. Darrith et al. reviewed 24 studies that assessed dislocation and revision rates after DMIs were implanted in pTHR [32]. They reported a dislocation rate of 0.5%, and a revision rate of 2.0% over 8.5 years. Additionally, they reported zero cases of IPD after 2007, nor for cases that used 28mm heads. Jonker et al. reviewed 5 case-control studies and 3 registry databases that had used DMIs in pTHR and compared them against standard unipolar prostheses [33]. Their review demonstrated dislocation rates of 0.2% (versus 7.1% in the unipolar group) and revision rates of 1.6% (versus 6.0%) in the case-control data, and revision rates of 2.7% (versus 1.5%) in the registry data (dislocation rates were not reported for registry data). These figures echo the findings of our analysis. De Martino et al. also reviewed DMI in
pTHR and reported a dislocation rate of 0.9% over 6.8 years [34]. Other reviews have assessed dislocation rates but have not separated pTHR and rTHR data.

**Implications of our findings**

In the UK, projections suggest a significant increase in the number of patients who will require a THR by the year 2035, particularly because of an ageing population with increasing life expectancy and increasing rates of obesity [35]. It can, therefore, be anticipated that there will be a disproportionate rise in the number of complications such as dislocations and their associated sequelae (including repeated hospitalisations and substantial health system costs). Recent data from the United States demonstrated a four-fold increase in the number of patients sustaining prosthetic hip dislocations between 2000 and 2017, driven increasing numbers of patients undergoing THR, which is anticipated to rise further by 2035 [36]. THR dislocation should be framed as a public health burden and there is a need to address it from this perspective. A greater understanding of the factors that influence THR dislocation is required, and careful consideration should be given to deciding which patients would benefit from CACs or DMIs. THR continues to be one of the commonest surgical procedures and remains a highly successful and cost-effective intervention for alleviating pain and disability associated with advanced hip joint disease [37–40]. Careful selection of implants for patients at risk of instability will permit this legacy to continue.

**Strengths and limitations**

To our knowledge, this is the first analysis to assess the overall and period-specific incidence and temporal trends in dislocation and revision rates following pTHR that has utilised CACs or DMIs. This analysis adhered stringently to the expected standards of investigation and reporting for a systematic review and meta-analysis. Risk of bias assessments were performed using validated tools, and comprehensive data verification techniques were used to ensure the accuracy of the included data and
statistics – in particular, to ensure that participants were not “double-counted” from multiple publications on the same cohort of patients. There were also several limitations. First, all data were observational, and the majority was retrospective, which inherently increases the risk of selection bias and confounding, and as such all included studies were deemed to be of serious or critical risk of bias overall. Second, factors surrounding dislocation after pTHR continue to be multifactorial and poorly understood, and the choice of an implant (CAC or DMI) is unlikely the sole reason for a dislocation. Third, there is a relative absence of literature providing longitudinal observational data after CACs have been implanted in pTHRs and this must be considered when interpreting the findings of this study. Finally, no included studies directly compared these two sets of implants.

Conclusions

Over a mean follow-up period of 4 years, the incidence of dislocation following a pTHR utilising CACs was 1.1%, compared to 0.3% after 6 years for DMIs. Temporal trends in dislocation have improved over time for DMIs, but there was insufficient data for a similar analysis of CACs. DMIs appear to be associated with lower rates of dislocation. A key limitation of this study is the relative absence of longitudinal observational studies of CACs used in the context of pTHR.
References


