Does hip preservation surgery prevent arthroplasty?
Quantifying the rate of conversion to arthroplasty following hip preservation surgery

Mark Andrew Sohatee 1*, Mohammed Ali 2, Vikas Khanduja 3 and Ajay Malviya 4

1Health Education North East, Waterfront 4, Goldcrest Way, Newcastle upon Tyne, NE15 8NY, UK,
2Department of Trauma and Orthopaedics, South Tyneside and Sunderland NHS Foundation Trust, Harton Ln, South Shields NE34 OPL, UK,
3Department of Trauma and Orthopaedics, Cambridge University Hospitals NHS Foundation Trust, Hills Road, Cambridge CB2 0QQ, UK and
4Department of Trauma and Orthopaedics, Northumbria NHS Foundation Trust, Unit 7-8 Silver Fox Way Cobalt Business Park, Silver Fox Way, Newcastle upon Tyne NE27 0QJ, UK.
*Correspondence to: M. A. Sohatee. E-mail: mark.sohatee@nhs.net
Submitted 22 November 2019; Revised 12 March 2020; revised version accepted 18 April 2020

ABSTRACT
Hip arthroscopic surgery for femoroacetabular impingement and periacetabular osteotomy (PAO) for dysplasia is the most commonly used contemporary treatment for these conditions and has been shown to provide pain relief and restore function. What is less understood and perhaps of more interest to health economists, is the role of these procedures in preserving the hip joint and avoiding hip arthroplasty. The aim of this systematic review was to determine whether hip joint preservation surgery, indeed, preserves the hip joint by looking at conversion rates to total hip arthroplasty (THA). Two separate searches were undertaken, using PRISMA guidelines and utilizing PubMed and Open Athens search engines, identifying manuscripts that looked at conversion to THA following either hip arthroscopy (HA) or PAO. When considering HA, we found 64 eligible papers. Out of these studies, there were 59 430 hips with 5627 undergoing conversion to THA (9.47% [95% CI 9.23–9.71%]) with a mean conversion time of 24.42 months. Regarding PAO, there were 46 eligible papers including 4862 patients who underwent PAO with subsequent conversion to THA in 404 patients (8.31% [95% CI 7.54–9.12%]). with a mean conversion time of 70.11 months. Certain features were associated with increased conversion rates, including increasing age, worsening arthritis and joint space <2 mm. This study demonstrates that the mean conversion rates to be <10% for HA and PAO, during the mean follow-up periods of included manuscripts. Joint preserving surgery appears to defer or at least delay the need for THA.

INTRODUCTION
Joint arthroplasty surgery for hip pathology has a historical track record of achieving good outcomes. With satisfaction rates of around 90% [1], it gives predictable pain relief and restoration of function in a large number of patients. However, when considering the younger patient, it is particularly important to consider implant survival. We know that around 90% of arthroplasties will survive up until 15 years [2] and around 85% will last 20 years [3] and for this reason, the prospect of revision surgery due to implant wear/failure, in elderly patients, becomes less of a concern. However, when managing younger patients with hip pathology, one must be acutely aware of the potential need for revision or multiple revision surgeries, given the
increased life expectancy and potentially increased physical demands of someone of younger age. Therefore, when considering the ‘young adult’ with hip pathology, it is important to be aware of surgeries that look to provide pain relief, restore function and preserve the native hip. Furthermore, joint preservation surgery may have a role in easing the economic burden associated with total hip arthroplasty (THA).

There is an established link between untreated femoroacetabular impingement (FAI) and hip dysplasia and osteoarthritis (OA) [4, 5]. The main surgeries used in the setting of young adult hip pathology are hip arthroscopy (HA) and periacetabular osteotomy (PAO). Arthroscopy is frequently used for FAI surgery [6], where there is a motion-related disorder of the hip, composed of clinical signs and imaging findings, which results in premature contact between the proximal femur and the acetabulum [7]. Commonly, a cam (abnormality of the shape of femoral head) and/or pincer (prominent acetabular rim) lesion may be present and arthroscopy allows one to address the intra-articular pathology, such as chondral damage or labral tears, as necessary [8]. PAO surgery is often utilized in situations where a patient has a degree of adult hip dysplasia that may not have been clinically present as a child but has subsequently become clinically apparent later in life, or for patients who have had ongoing sequelae of appropriately managed paediatric dysplasia. Having been developed by Ganz [9], the aim of the PAO is to reorient the acetabulum, reducing superolateral acetabular inclination, improving femoral head coverage, translating the joint centre medially and normalizing loading of the anterolateral acetabular rim to prevent disease progression. The aim of these procedures is 2-fold as follows:

1. to improve pain and function, something that is well described in the literature and [10]
2. to preserve the hip joint, which the authors feel has not been clearly explored yet.

These surgical strategies offer a solution to young adult hip pathology that allows joint preservation. It is recognized that despite patients undergoing joint preservation surgery, a number of patients subsequently need to go on to have arthroplasty, which may be considered a failure of the joint preservation surgery. However, even if patients are to eventually undergo subsequent arthroplasty HA and PAO may be considered successful by deferring the need for THA until later in life.

Therefore, the aim of this paper was to determine the incidence of conversion to THA, following hip preservation surgery along with time to conversion, for those who underwent subsequent THA.

**MATERIALS AND METHODS**

**Study design**

This systematic review was constructed using the 2009 PRISMA [11] guidelines and relevant studies were identified by searching papers via the PubMed and Open Athens search engines searching the AMED, Medline, CINAHL, PubMed, HBE and OVID/Embase databases. We undertook two separate literature reviews to look at each of these interventions and assess their effect as joint preserving surgeries. The primary outcome measure we used for this literature review was looking at conversion rate to THA.

**Search strategy**

The searches of the aforementioned databases were last performed in November 2018. There was no restriction to dates where articles will be included from inception. The search subsequently included articles from other sources via cross-referencing that were added to the final pool of studies.

The search strategies used were:

((hip arthroscopy)) AND ((Conversion) OR (THA) OR (THR) OR (arthroplasty) OR (replacement) OR (survival)) - for articles relating to hip arthroscopy

((Periacetabular osteotomy) OR (Bernese osteotomy) OR (Ganz Osteotomy)) AND ((Conversion) OR (THA) OR (THR) OR (arthroplasty) OR (replacement) OR (survival)) - for articles relating to PAO

**Study selection**

Studies were the screened according to the inclusion and exclusion criteria. Papers considered for inclusion criteria were those that looked at outcomes for HA or PAO surgery, where THA was measured as an endpoint. We excluded articles if they were case reports, conference abstracts or instructional papers. There were numerous papers that were excluded due to them containing duplicate datasets, however, a number of papers were included where there was/may have been small overlap of datasets, due to minimal overlay of study periods stated and at the expense of not capturing relevant data, these papers were included. We, further, excluded papers if they were looking at revision HA, dealt with open or combined open
results
In this review, papers pertaining to HA had shorter follow-up (mean of mean follow-ups 46.41 months) compared with PAO (mean of mean follow-ups 85.5 months), this was statistically significant at $P < 0.001$.

The mean of mean time to conversion for PAO was significantly longer than that for HA (24.42 versus 70.11 months) $P < 0.001$.

FAI: hip arthroscopy
Our literature search identified 1462 papers and 3 papers were found via cross-referencing. Duplicate papers were removed, leaving 698 papers (Fig. 1).

After review of manuscript titles and abstract, 592 papers were excluded and after review of the full-text manuscript, a further 47 were excluded. This left a total of 62 papers [14–75].

Evidence
From the 62 papers included in our study, 1 paper of Level 2b, 5 papers of Level 3b and 57 papers of Level 4 evidence.

Mean MINORS scores for non-comparative studies were 10 and 17 for comparative studies.

Key findings
The key findings of the studies along with outcome for conversion rates to THA are included in Table 1. Upon analysis, there were 59 430 hips looked at with 5627 that underwent conversion to THA, giving a percentage conversion of 9.47% [95% CI 9.23–9.71%]. For papers that stated mean age, the mean age from these was 40.33 years. Where papers stated their mean follow-up, in a way that could be analysed; the range was 9.9–156 months and this gave a mean follow-up time, for all papers of 46.41 months. Where papers stated the mean conversion to THA in a way that could be analysed; the range was 8 months to 96 months, and this gave a mean conversion time for all papers of 24.42 months.

While many papers made reference to the mean age of patients and its implication on conversion, four papers [22, 34, 39, 54] presented data, related to age groups, in a way that could be analysed. This included 256 patients. These four papers looked to compare those under 40 years of age versus over 40 years of age. From these four papers, there were 29 out of 142 hips (20.4% [95% CI 14.1–28.0%]) under 40, which underwent HA and were subsequently converted to THA, versus 47 out of 114 hips (41.2% [95% CI 32.1–50.83%]) of patients over 40. On statistical analysis, this was statistically significant at $P < 0.001$.

Mean follow-up, for these papers, where stated, was longer than the mean of all papers at 94.3 months versus
35.8 months and mean time to conversion was 35.8 months versus 23.8 months for all papers, this may contribute to the higher percentage of conversion; however, these mean values, for these papers, were not statistically significantly different from the remaining papers.

Four papers [13, 22, 34, 64] looked at the prevalence of conversion to THA based on their grade of OA and presented data in a way that could be analysed. This included 235 patients. In order to standardize arthritis, the authors categorized it as non/mild–moderate and severe, where Outerbridge (0/1/2), Tonnis (0/1), Kellegren-Lawrence (0/1/2)—was non/mild–moderate and Outerbridge (3/4), Tonnis (2/3), Kellegren-Lawrence (3/4)—was severe. Where authors reported more than one, Tonnis grade was used preferentially.

From these papers, 14 out of 115 (12.17% [95% CI 6.81–19.58%]) of all patients with non/mild–moderate OA underwent conversion to THA versus 61 out of 120 (50.83% [95% CI 41.55–60.07%]) of patients with moderate to severe OA. This was statistically significant at \( P < 0.001 \).

Three papers [30, 33, 72] looked at the prevalence of conversion to THA based on joint space narrowing and presented data in a way that could be analysed. This included 599 patients. Out of those with >2 mm joint space, 84 out of 513 (16.37% [95% CI 13.28–19.87%]) underwent THA versus 69 out of 86 (80.23% [95% CI 70.25–88.04%]) of patients with a joint space of <2 mm. This was statistically significant at \( P < 0.001 \), suggesting reduced joint space may be a risk factor for conversion to THA after HA.

**Periacetabular osteotomy**

Our literature search identified 560 papers and 10 papers were found via cross-referencing. Duplicate papers were removed, leaving 230 papers. After review of manuscript titles and abstract, 162 papers were excluded and after review of the full-text manuscript, a further 22 were excluded. This left a total of 46 papers [76–119].

**Evidence**

From the 46 papers included in our study, there were: 2 papers of Level 2b, 3 papers of Level 3b and 41 papers of
| Author            | Year | Level of evidence | MINORS score | Number of hips | Mean age | Hips converted | Mean (or median) follow-up (months) | Mean time to conversion (months) |
|-------------------|------|-------------------|--------------|----------------|----------|---------------|-------------------------------------|-------------------------------|
| Farjo et al.      | 1999 | 4                 | 12           | 28             | 41       | 6            | 34                                  | 14                            |
| Londers et al.    | 2007 | 4                 | 10           | 56             | 34       | 7            | 72                                  | 27                            |
| Byrd et al.       | 2008 | 4                 | 12           | 207            | 33       | 1            | 16                                  | 8                             |
| Ilizaliturri et al.| 2008 | 4               | 11           | 19             | 34       | 1            | Minimum 36                          | Not stated                    |
| Larson et al.     | 2008 | 4                 | 12           | 100            | 34.7     | 3            | 9.9                                 | Not stated                    |
| Kamath et al.     | 2009 | 4                 | 12           | 52             | 42       | 3            | 57.6                                | 8                             |
| Philippon et al.  | 2009 | 4                 | 10           | 112            | 40.6     | 10           | 27.6                                | 16                            |
| Gedouin et al.    | 2010 | 4                 | 12           | 111            | 31       | 5            | 10                                  | 12                            |
| Haviv et al.      | 2010 | 4                 | 10           | 564            | 55       | 90           | 38.4                                | 18                            |
| Horisberger et al.| 2010 | 4               | 12           | 19             | Not stated | 10          | 36                                  | 16.8                          |
| Mccarthy et al.   | 2010 | 4                 | 10           | 111            | 39       | 49           | 156                                 | 57.6                          |
| Singh et al.      | 2010 | 4                 | 10           | 27             | 22       | 0            | 22                                  | NA                            |
| Byrd et al.       | 2011 | 4                 | 10           | 200            | 28.6     | 1            | 19                                  | Not stated                    |
| Byrd et al.       | 2011 | 4                 | 12           | 100            | 34       | 0            | 10                                  | NA                            |
| Javed et al.      | 2011 | 4                 | 10           | 40             | 65       | 7            | 30                                  | 12                            |
| Konan et al.      | 2011 | 4                 | 12           | 100            | 32       | 6            | Not stated                          | Not stated                    |
| Meftah et al.     | 2011 | 4                 | 12           | 50             | 40.1     | 2            | 100.8                               | 58.2*                         |
| Schilders et al.  | 2011 | 4                 | 10           | 101            | 37       | 0            | 29.28                               | NA                            |
| Mccormick et al.  | 2012 | 4                 | 8            | 176            | 40.9     | 20           | 51.6                                | 31.2                          |
| Palmer et al.     | 2012 | 4                 | 10           | 201            | 40.2     | 13           | 46                                  | 17.7                          |
| Bogunovic et al.  | 2013 | 4                 | 10           | 1724           | Not stated | 60          | Not stated                          | 31                            |
| Boykin et al.     | 2013 | 4                 | 11           | 23             | 28       | 2            | 41.1                                | Not stated                    |
| Geyer et al.      | 2013 | 4                 | 12           | 76             | 38.5     | 19           | 49                                  | 28                            |
| Matsuda et al.    | 2013 | 3b                | 16/24        | 54             | 34.6     | 0            | 30                                  | NA                            |
| Philippon et al.  | 2013 | 4                 | 10           | 96             | 57       | 41           | 54                                  | 23                            |
| Jackson et al.    | 2014 | 4                 | 12           | 54             | 28.8     | 2            | 28.8                                | 18                            |
| Krych et al.      | 2014 | 4                 | 14           | 59             | 46       | 7            | 60                                  | Not stated                    |
| Nielsen et al.    | 2014 | 4                 | 12           | 117            | 37       | 5            | Not stated                          | Not stated                    |
| Skendzel et al.   | 2014 | 4                 | 11           | 466            | 39.6     | 117          | 73                                  | 31.6                          |
Table I. (continued)

| Author          | Year | Level of evidence | MINORS score | Number of hips | Mean age | Hips converted | Mean (or median) follow-up (months) | Mean time to conversion (months) |
|-----------------|------|-------------------|--------------|----------------|----------|----------------|--------------------------------------|---------------------------------|
| Wilkin et al.   | 2014 | 4                 | 12           | 41             | 52.7     | 6              | 34.8                                 | 18.8                            |
| Bedard et al.   | 2015 | 4                 | 8            | 1577           | Not stated| 84             | Not stated                           | 12                              |
| Cetinkaya et al.| 2015 | 3^a              | 18/24        | 73             | 33.5/39.5| 3              | 45.2/47.2                           | 16                              |
| Daivajna et al. | 2015 | 4                 | 12           | 77             | 43       | 34             | 33.6                                 | 18                              |
| Fiorenino et al.| 2015 | 4                 | 12           | 38             | 44.4     | 2              | 36                                   | 24.3                            |
| Krych et al.    | 2015 | 3^a              | 19/24        | 104            | 41       | 2              | Not stated                           | Not stated                      |
| Malviya et al.  | 2015 | 4                 | 8            | 6935           | 38       | 680            | 28.8                                 | 16.8                            |
| Sansone et al.  | 2015 | 4                 | 11           | 75             | 47       | 5              | 26                                   | Not stated                      |
| Sing et al.     | 2015 | 4                 | 8            | 8277           | Not stated| 720^a         | Not stated                           | Not stated                      |
| Capogna et al.  | 2016 | 4                 | 12           | 42             | 65.8     | 3              | 26.4                                 | Not stated                      |
| Comba et al.    | 2016 | 4                 | 12           | 42             | 38       | 7              | 91                                   | 33                              |
| Haefeli et al.  | 2016 | 4                 | 10           | 52             | 35       | 2              | 79                                   | 96^a                            |
| Hermann et al.  | 2016 | 4                 | 8            | 79             | 48.6     | 18             | 32                                   | Not stated                      |
| Hufeland et al. | 2016 | 4                 | 10           | 44             | 34.3     | 5              | 66.3                                 | 28                              |
| Kremmers et al. | 2016 | 4                 | 8            | 10 402        | 41.3     | 1096           | 28.8                                 | Not stated                      |
| Mardones et al. | 2016 | 4                 | 10           | 28             | 63.4     | 3              | 52.8                                 | 12                              |
| Schairer et al. | 2016 | 4                 | 8            | 7351           | 43.9     | 912^a         | Not stated                           | Not stated                      |
| Degen et al.    | 2017 | 4                 | 8            | 8267           | Not stated| 796            | Not stated                           | 19.9                            |
| Locks et al.    | 2017 | 3^a              | 17/24        | 11             | 35       | 0              | 62                                   | NA                             |
| Menge et al.    | 2017 | 4                 | 11           | 145            | Not stated| 50             | Not stated                           | Not stated                      |
| Moriya et al.   | 2017 | 4                 | 10           | 23             | 59       | 1              | 28                                   | 13                              |
| Tjong et al.    | 2017 | 4                 | 10           | 106            | 38.1     | 0              | 37.2                                 | NA                             |
| Truntzer et al. | 2017 | 4                 | 8            | 2581           | Not stated| 88             | Not stated                           | Not stated                      |
| Cvetanovich et al.| 2018 | 4               | 10           | 474            | 33.3     | 7              | 31.2                                 | Not stated                      |
| Domb et al.     | 2018 | 4                 | 10           | 1038           | 36.4     | 66             | 30.1                                 | Not stated                      |
| Kaldau et al.   | 2018 | 4                 | 10           | 84             | 40.4     | 15             | 82.9                                 | Not stated                      |
| Kester et al.   | 2018 | 4                 | 8            | 3957           | 35.8     | 235            | Not stated                           | 14.7                            |
| Maldonado et al.| 2018 | 2^a              | 16/24        | 743            | 27.8/34.1| 11             | 42.5/43.9                           | 38.7/35.1                      |
| McCarthy et al. | 2018 | 4                 | 10           | 989            | 41.1     | 210            | Not stated                           | Not stated                      |
Level 4 evidence. Mean MINORS score for non-comparative studies was 9 for non-comparative and 16 for comparative (Fig. 2).

**Key findings**
The key findings of the studies along with outcome for conversion rates to THA are included in Table II. Upon analysis, there were 4862 hips looked at with 404 that underwent conversion to THA, giving a percentage conversion of 8.31% (95% CI 7.54–9.12%). For papers that stated mean age, the mean age from these was 30.08 years. Where papers stated their mean follow-up in a way that could be analysed; the range was 14–348 months and this gave a mean follow-up time, for all papers of 85.5 months.

---

Table I. (continued)

| Author         | Year | Level of evidence | MINORS score | Number of hips | Mean age | Hips converted | Mean (or median) follow-up (months) | Mean time to conversion (months) |
|----------------|------|-------------------|--------------|----------------|----------|----------------|-------------------------------------|---------------------------------|
| Olach et al.   | 2018 | 4                 | 9            | 92             | 36       | 11             | 134.4                               | Not stated                      |
| Perets et al.  | 2018 | 4                 | 10           | 12             | 39.9     | 1              | 45                                  | 24                              |
| Philippon et al.| 2018 | 3\(^a\)           | 15/24        | 99             | 29       | 4              | Not stated                          | 31.25\(^a\)                     |
| Schutler et al.| 2018 | 4                 | 11           | 529            | 43.9     | 63             | Not stated                          | Not stated                      |

\(^a\)Value calculated from data.
Table II. Results for PAO

| Author                | Year | Level of evidence | MINORS score | Number of hips | Mean age | Hips converted | Mean/median follow-up (months) | Mean time to conversion (months) |
|-----------------------|------|-------------------|--------------|----------------|----------|----------------|-------------------------------|---------------------------------|
| Crockerell et al.     | 1999 | 4                 | 8            | 21             | Not stated | 1              | 38                            | Not stated                      |
| Davey et al.          | 1999 | 4                 | 10           | 70             | Not stated | 0              | Not stated                    | Not stated                      |
| Matta et al.          | 1999 | 4                 | 8            | 66             | 33.6      | 5              | 48                            | 85.2                            |
| Mayo et al.           | 1999 | 4                 | 6            | 19             | 30.9      | 2              | 45                            | 18/67                           |
| Murphy et al.         | 1999 | 3<sup>a</sup>     | 12/24        | 195            | 29        | 2              | 36–94                         | Not stated                      |
| Trumble et al.        | 1999 | 4                 | 10           | 123            | 32.9      | 7              | 51.6                          | 41                              |
| Valenzuela et al.     | 2004 | 4                 | 8            | 94             | 32        | 2              | 45.6                          | Not stated                      |
| Kralj et al.          | 2005 | 4                 | 10           | 26             | 34        | 4              | 144                           | 54                              |
| Pogliacomi et al.     | 2005 | 4                 | 10           | 32             | Not stated | 3              | 48                            | 72                              |
| Peters et al.         | 2006 | 4                 | 10           | 83             | 28        | 3              | 46                            | 36                              |
| Bernstein et al.      | 2007 | 4                 | 16/24        | 47             | 20–27     | 1              | 228                           | 12                              |
| Clohisy et al.        | 2007 | 4                 | 10           | 24             | 22.7      | 0              | 46.8                          | Not stated                      |
| Garras et al.         | 2007 | 4                 | 10           | 58             | 37.6      | 4              | 66.7                          | 36                              |
| Badra et al.          | 2008 | 4                 | 8            | 36             | 27.9      | 3              | 42                            | Not stated                      |
| Troelsen et al.       | 2008 | 2<sup>a</sup>     | 18/24        | 263            | 31/35     | 15             | • 58.8–110.4                  | 52.8/26                         |
|                       |      |                   |              |                |           |                |                               | • 12.0–48.8                     |
|                       |      |                   |              |                |           |                |                               | • 12.0–58.8                     |
| Armiger et al.        | 2009 | 4                 | 10           | 12             | 35        | 1              | 24                            | 36                              |
| Matheney et al.       | 2009 | 4                 | 10           | 135            | 23.9      | 17             | 108                           | 73.2                            |
| Millis et al.         | 2009 | 4                 | 10           | 87             | 43.6      | 21             | 58.8                          | 62.4                            |
| Burke et al.          | 2011 | 4                 | 10           | 85             | 22.9      | 4              | 59                            | Not stated                      |
| Howie et al.          | 2011 | 4                 | 10           | 26             | 28        | 3              | 120                           | Not stated                      |
| Ito et al.            | 2011 | 4                 | 10           | 175            | 47.2/27.1 | 7              | 132                           | Not stated                      |
| Kain et al.           | 2011 | 3<sup>a</sup>     | 16/24        | 17/34          | 31        | 3              | 56.4/31.2                     | 169.2<sup>a</sup>              |
| Ziebarth et al.       | 2011 | 4                 | 10           | 46             | 23.5      | 1              | 43                            | 18                              |
| Hartig-Andreasen et al. | 2012 | 4                 | 10           | 401            | 33.9      | 69             | 96                            | Not stated                      |
| Polkowski et al.      | 2012 | 4                 | 8            | 67             | 19.2      | 5              | 60                            | 79                              |
| Sang do Kim et al.    | 2012 | 4                 | 10           | 43             | 28        | 5              | 32                            | Not stated                      |
| Albers et al.         | 2013 | 4                 | 8            | 165            | 28/29     | 19             | 132                           | Not stated                      |
| Tannast et al.        | 2013 | 4                 | 6            | 26             | 23        | 7              | 56.4                          | Not stated                      |
| Zhu et al.            | 2013 | 4                 | 10           | 41             | 39.5      | 1              | 61.2                          | 108                             |

(continued)
Where papers stated the mean conversion to THA in a way that could be analysed; the range was 12–192 months, and this gave a mean conversion time for all papers of 70.11 months.

Only one paper [96] presented data, related to age groups, in a way that could be analysed. This included 158 patients comparing those under 40 years of age versus over 40 years of age. From this paper, there were 4 out of 117 hips (3.42% [95% CI 0.93–8.52%]) under 40, that PAO and were subsequently converted to THA versus 3 out of 38 hips (7.89% [95% CI 16.59–21.38%]) of patients over 40. On statistical analysis, this was not statistically significant at $P = 0.385$.

Seven papers [86, 91, 95, 100, 101, 105, 115] looked at the prevalence of conversion to THA based on their grade of OA and presented data in a way that could be analysed. This included 660 patients. In order to standardize arthritis, the authors categorized it as non/mild–moderate and severe, where Outerbridge (0/1/2), Tonnis (0/1), Kellegren-Lawrence (0/1/2)—was non/mild–moderate and Outerbridge (3/4), Tonnis (2/3), Kellegren-Lawrence (3/4)—was severe. Where authors reported more than one, Tonnis grade was used preferentially.

From these papers, 74 out of 576 (12.85% [95% CI 10.22–15.86%]) of all patients with non/mild–moderate OA underwent conversion to THA versus 43 out of 84 (51.19% [95% CI 40.03–62.26%]) of patients with moderate to severe OA. The difference between groups was statistically significant at $P < 0.001$, suggesting increasing arthritis may be a risk factor for conversion to THA after PAO.

One paper [115] looked at conversion rates to THA based on joint space. This included 126 with data for 117 patients. Those with $>2$ mm joint space, 9 out of 80
(11.25% [95% CI 5.28–20.28%]) underwent conversion and those with ≤2 mm, 15 out of 37 (40.54% [95% CI 24.75–57.90%]) underwent conversion. The difference between groups was statistically significant at \( P < 0.001 \) and suggests that reduced joint space may be a risk factor for conversion to THA after PAO.

**DISCUSSION**

The association between FAI and OA was the subject of a recent systematic review [120] and it is clear that despite the exponential increase in the number of HAs performed [121], explicit evidence reporting longer-term outcomes and subsequently supporting long-term success is limited. We also know that developmental dysplasia of the hip, and its subsequent structural instability, is known to be a cause of secondary OA [4, 5]. Arthroscopic intervention is minimally invasive and aims to deal with FAI by addressing congruity of the joint by dealing with cam and/or pincer pathologies and managing the secondary intra-articular pathology of labral tear. The PAO on the other hand is a bigger operation involving an osteotomy of the pelvis to reorient the acetabulum, to correct aberrant acetabular morphology and improve femoral head coverage. The Bernese group, where Ganz first described the PAO [9], have published their 20-year follow-up [122] and 30-year follow-up [101], with the most up to date paper included in this review article.

While the authors recognize that there are other treatment options available, such as open impingement procedures and alternative osteotomies, HA and PAO are the most frequently used techniques in the adult population. The ultimate aim of these procedures is to, both, improve symptoms that arise from hip joint pathology including pain, reduced movement/mobility and to preserve the hip joint of a patient with underlying pathology.

With respect to risk factors for conversion, for HA, age >40, moderate to severe OA and a joint space of ≤2 mm was associated with statistically significant differences in conversion rates. For PAO, statistically significant differences in conversion rates were seen when arthritis was moderate to severe and joint space was ≤2 mm.

A number of studies have shown increasing age to result in higher conversion rates to joint arthroplasty following hip preservation surgery [22, 54, 57, 83, 96, 102, 123–126]. For HA age >40 was demonstrated by McCarthy et al. [54] to result in an increased rate of conversion to THA, whereas Comba et al. [22] identified 45 and Capogna et al. [20, 127] identified 60. Malviya et al. [49] have demonstrated in a series of 6395 patients undergoing hip arthroscopic intervention that the odds of conversion to THA is 4.65 times higher in patients over the age of 50 compared with under the age of 50. The majority of the literature, regarding PAO outcomes, pertains to patient under the age of 40, however, age has been demonstrated as a risk factor for conversion to THA [83, 102] and where they are performed in patients over the age of 40, this may result in increased rates of conversion to THA [92].

As aforementioned arthritis and degenerative features, in their own right, along with reduced joint space, particularly a joint space of <2 mm [54, 57, 65, 123–125, 128, 129] were also associated with conversion to THA in arthroscopy and these features were also a predictor shared by several authors when looking at PAO [78, 84, 86, 88, 99, 108].

Other systematic reviews looking at only HA cohort have had similar findings to ours. Domb et al. [130] in a 13 paper systematic review, looking at the outcomes of HA, noted that there was a significantly higher conversion rate to THA in the presence of established arthritis, with 8.3% of patients requiring hip arthroplasty in the non-OA group, versus 23% requiring conversion to THA in the arthritic group, with a mean time to conversion of 26 months and 17.1 months, respectively (\( P < 0.01 \)).

Another review by Kemp et al. [131], looking at HA in the context of OA, noted that the progression to THR post-arthroscopy ranged from 7 months to 4.8 years. Regarding PAO, Clohisy et al.’s review found [132] that clinical failures were commonly associated with moderate to severe pre-operative OA and conversion to THA was reported in 0–17% of cases. Major complications were noted in 6–37% of the procedures. These data indicate that PAO provides pain relief and improved hip function in most patients over short- to mid-term follow-up. The current evidence is primarily Level 4.

It is evident, from the size of the studies included in this review, that larger studies of better quality are required to evaluate the usefulness of these procedures with a mean sample size of 958 from the HA studies and 107 for the PAO studies. The quality of the papers was also poor, highlighted by their MINORS scores and the lack of Level 1 and Level 2 evidence. However, the results of this paper are certainly suggestive of the fact that joint preservation surgery can be an efficacious way of addressing young adult hip pathology and preserving the hip joint in the short to medium term. The authors feel that an effective way to analyse large amounts of data is to look at population-based studies, such as the largest study in our series by Malviya et al. [49] which looked at HA in 6395 patients with a median 2.4-year follow-up (range: 0.5–8.2 years). This demonstrated a survival analysis over an 8-year period, with an 82.6% survival rate and a THA rate of 680 patients (10.6%) with a mean time to conversion of
1.4 years. Malviya et al.’s findings for HA are aligned with the findings of our study. Hartig-Andreasen et al.’s series, which was the largest of the PAO papers [92], which included 401 hips, reported 69 hips converted to THR at 3.9–12.4 years following the PAO. The overall Kaplan-Meier hip survival rate was 74.8% at 12.4 years.

The authors propose that larger studies can be achieved through the use of procedure registries and a number of the HA papers were able to report larger numbers due to registry use. In the UK, the Non-Arthroplasty Hip Registry is established, aiming to capture all operations around the hip which are not arthroplasty or for acute trauma. With patient compliance to follow-up being a barrier to good quality mid- to long-term studies, having a registry and further developing an infrastructure to facilitate such follow-up may provide useful data to improve surgical practise. While there is benefit in knowing the results of surgery by individual surgeons, like the majority of papers in this review, there is an inherent risk of publication bias, with most studies being performed, reported, cited and published by high-volume surgeons. Population-based studies help us understand and explore the results in ‘non-expert’ hands.

There are also other significant limitations of this study. The papers are included are incredibly heterogeneous with no standardization of operative intervention or post-operative rehabilitation, potentially giving significant variability in results. It does also not consider the functional outcomes and purely looks at conversion rate, using conversion to THA as a surrogate for success or failure. Clearly the issue is a more complex one, with not all failures undergoing conversion. Furthermore, when looking at risk factors for conversions, few papers presented raw data in a way that could be analysed, detracting from statistical analysis. When considering what patients want, one would assume that their main desires are to be pain free and have good function. The potential importance of patients keeping one’s hip joint is important to health services and clinicians; to limit technically demanding revision procedures and the potential complications associated with arthroplasty, as well as quelling the economic burden of arthroplasty, however, the importance of hip joint preservation to patients are unknown and the authors feel there should be more evidence on functional outcomes for joint preservation surgery, ideally building on the information gleaned from the UK FASHiON trial [133] and, ongoing FAIT trial [134], through sufficiently powered randomized control trials comparing non-operative management to joint preservation surgery.

We have focused on the conversion to THA in this study and when considering this factor, the results appear favourable, in the short to medium term at least, when one considers that <10% of patients are undergoing conversion. More long-term evidence is available for PAOs compared with HAs but clearly more robust evidence will be required to strengthen the argument in favour of hip-preserving surgery. The findings do, however, highlight that patient selection is crucial to achieving good outcomes.

**CONFLICT OF INTEREST STATEMENT**

Mark Andrew Söyleve - Non Declared. Mohammed Ali - Non Declared. Vikas Khanduja; Associate editor BJJ. NAHR Past Chair/Board member, Educational consultant for Smith and Nephew and Arthrex Ajay Malviya; NAHR Chair/Board member, Deputy Editor JHPS.

**REFERENCES**

1. Kay A, Davison B, Badley E, Wagstaff S. Hip arthroplasty: patient satisfaction. *Br J Rheumatol* 1983; 22: 243–9.
2. Eskelinen A, Remes V, Helenius I et al. Uncemented total hip arthroplasty for primary osteoarthritis in young patients: a mid-to long-term follow-up study from the Finnish Arthroplasty Register. *Acta Orthop* 2006; 77: 57–70.
3. Schulte KR, Callaghan JJ, Kelley SS et al. The outcome of Charnley total hip arthroplasty with cement after a minimum twenty-year follow-up. The results of one surgeon. *J Bone Joint Surg Am* 1993; 75: 961–75.
4. Ganz R, Parvizi J, Beck M et al. Femorocacetabular impingement: a cause for osteoarthritis of the hip. *Clin Orthop Relat Res* 2008; 466: 273–120.
5. Jacobsen S, Sonne-Holm S. Hip dysplasia: a significant risk factor for the development of hip osteoarthritis. A cross-sectional survey. *Rheumatology* 2005; 44: 211–8.
6. Bedi A, Kelly BT, Khanduja V. Arthroscopic hip preservation surgery: current concepts and perspective. *Bone Joint J* 2013; 95B: 10–9.
7. Griffin DR, Dickenson EJ, O’Donnell J et al. The Warwick Agreement on femorocacetabular impingement syndrome (FAI syndrome): an international consensus statement. *Br J Sports Med* 2016; 50: 1169–76.
8. McCarthy JC, Noble PC, Schuck MR et al. The Otto E. Aufranc Award: the role of labral lesions to development of early degenerative hip disease. *Clin Orthop Relat Res* 2001; 393: 25–37.
9. Siebenrock KA, Schöll E, Lottenbach M et al. Bernese periacetabular osteotomy. *Clin Orthop Relat Res* 1999; 363: 9–20.
10. Klot J, Hartig-Andreasen C, Jacobsen S et al. Periacetabular osteotomy: sporting, social and sexual activity 9-12 years postsurgery. *Hip Int* 2014; 24: 27–31.
11. Moher D, Liberati A, Tetzlaff J et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *J Clin Epidemiol* 2009; 62: 1006–12.
12. Oxford Centre for Evidence-based Medicine – Levels of Evidence. Centre for Evidence-Based Medicine. 2009; Available at: https://www.cebm.net/2009/06/oxford-centre-evidence-
16. Boykin RE, Patterson D, Briggs KK et al. Results of arthroscopic labral reconstruction of the hip in elite athletes. *Am J Sports Med* 2013; 41: 2296–301.

17. Byrd JW, Jones KS. Arthroscopic femoroplasty in the management of cam-type femoroacetabular impingement. *Clin Orthop Relat Res* 2009; 467: 739–46.

18. Byrd JW, Jones KS. Arthroscopic management of femoroacetabular impingement in athletes. *Am J Sports Med* 2011; 39: 7–13.

19. Byrd JW, Jones KS. Arthroscopic management of femoroacetabular impingement: minimum 2-year follow-up. *Arthroscopy* 2011; 27: 1379–88.

20. Capogna BM, Ryan MK, Begly JP et al. Clinical outcomes of hip arthroscopy in patients 60 or older: a minimum of 2-year follow-up. *Arthroscopy* 2016; 32: 2505–10.

21. Cetinkaya S, Toker B, Ozden VE et al. Arthroscopic labral repair versus labral debridement in patients with femoroacetabular impingement: a minimum 2.5 year follow-up study. *Hip Int* 2016; 26: 20–4.

22. Comba F, Yacuzzi C, Ali PJ et al. Joint preservation after hip arthroscopy in patients with FAI. Prospective analysis with a minimum follow-up of seven years. *Muscles Ligaments Tendons J* 2015; 9: 317–23.

23. Cvetanovich GL, Weber AE, Kuhns BD et al. Hip arthroscopic surgery for femoroacetabular impingement with capsular management: factors associated with achieving clinically significant outcomes. *Am J Sports Med* 2018; 46: 88–96.

24. Daiva J, Bajwa A, Villar R. Outcome of arthroscopy in patients with advanced osteoarthritis of the hip. *PLoS One* 2015; 10: e0113970.

25. Degen RM, Pan TJ, Chang B et al. Risk of failure of primary hip arthroscopy-a population-based study. *J Hip Preserv Surg* 2017; 4: 214–23.

26. Domb BG, Martin TJ, Gru C et al. Predictors of clinical outcomes after hip arthroscopy: a prospective analysis of 1038 patients with 2-year follow-up. *Am J Sports Med* 2018; 46: 1324–30.

27. Farjo LA, Glick JM, Sampson TG. Hip arthroscopy for acetabular labral tears. *Arthroscopy* 1999; 15: 132–7.

28. Fiorentino G, Fontanarosa A, Cepparulo R et al. Treatment of cam-type femoroacetabular impingement. *Joints* 2015; 5: 67–71.

29. Gedouin JE, May O, Bonin N et al. Assessment of arthroscopic management of femoroacetabular impingement. A prospective multicenter study. *Orthop Traumatol Surg Res* 2010; 96: S59–67.

30. Geyer MR, Philippon MJ, Fagrelis TS et al. Acetabular labral reconstruction with an iliotibial band autograft: outcome and survivorship analysis at minimum 3-year follow-up. *Am J Sports Med* 2013; 41: 1750–6.
Does hip preservation surgery prevent arthroplasty?

47. Londers J, Van Melkebeek J. Hip arthroscopy: outcome and patient satisfaction after 5 to 10 years. Acta Orthop Belg 2007; 73: 478–83.

48. Maldonado DR, Krych AJ, Levy BA et al. Does iliosposa lengthening adversely affect clinical outcomes after hip arthroscopy? A multicenter comparative study. Am J Sports Med 2018; 46: 2624–31.

49. Malviya A, Raza A, Jameson S et al. Complications and survival analyses of hip arthroscopies performed in the national health service in England: a review of 6,395 cases. Arthroscopy 2015; 31: 836–42.

50. Maradit Kremers H, Schilz SR, Van Houten HK et al. Trends in utilization and outcomes of hip arthroscopy in the United States between 2005 and 2013. J Arthroplasty 2017; 32: 750–5.

51. Mardones R, Via AG, Rivera A et al. Arthroscopic treatment of femoroacetabular impingement in patients older than 60 years. Muscles Ligaments Tendons J 2019; 6: 397–401.

52. Matsuda DK, Burchette RJ. Arthroscopic hip labral reconstruction with a gracilis autograft versus labral refixation: 2-year minimum outcomes. Am J Sports Med 2013; 41: 980–7.

53. McCarthy B, Ackerman IN, de Steiger R. Progression to total hip arthroplasty following hip arthroscopy. ANZ J Surg 2013; 83: 2019; 73: 2624–31.

54. McCartney JC, Jarrett BT, Ojeifo O et al. What factors influence long-term survivorship after hip arthroscopy? Clin Orthop Relat Res 2011; 469: 362–71.

55. McCormick F, Nwachukwu BU, Alpaugh K, Martin SD. Predictors of hip arthroscopy outcomes for labral tears at minimum 2-year follow-up: the influence of age and arthritis. Arthroscopy 2012; 28: 1359–64.

56. Meftah M, Rodriguez JA, Panagopoulos G et al. Long-term results of arthroscopic labral debridement: predictors of outcomes. Orthopedics 2011; 34: e588–92.

57. Menge TJ, Briggs KK, Dornan GJ et al. Survivorship and outcomes 10 years following hip arthroscopy for femoroacetabular impingement: labral debridement compared with labral repair. J Bone Joint Surg Am 2017; 99: 997–1004.

58. Moriya M, Fukushima K, Uchiyama K et al. Clinical results of arthroscopic surgery in patients over 50 years of age: what viability does it have as a joint preserving surgery? J Orthop Surg Res 2017; 12: 2.

59. Nielsen TG, Miller LL, Lund B et al. Outcome of arthroscopic treatment for symptomatic femoroacetabular impingement. BMC Musculoskelet Disord 2014; 15: 394.

60. Olach M, Gerhard P, Giesinger K et al. Clinical and radiological outcome at mean follow-up of 11 years after hip arthroscopy. Arch Orthop Trauma Surg 2019; 139: 1–6.

61. Palmer DH, Ganesh V, Comfort T et al. Midterm outcomes in patients with cam femoroacetabular impingement treated arthroscopically. Arthroscopy 2012; 28: 1671–81.

62. Perets I, Chahabarbash EO, Mu B et al. Hip arthroscopy in patients ages 50 years or older: minimum 5-year outcomes, survivorship, and risk factors for conversion to total hip replacement. Arthroscopy 2018; 34: 5001–9.

63. Philippon MJ, Boria IK, Locks R et al. Labral preservation: outcomes following labrum augmentation versus labrum reconstruction. Arthroscopy 2018; 34: 2604–11.

64. Philippon MJ, Briggs KK, Carlisle JC et al. Joint space predicts THA after hip arthroscopy in patients 50 years and older. Clin Orthop Relat Res 2013; 471: 2492–6.

65. Philippon MJ, Briggs KK, Yen YM et al. Outcomes following hip arthroscopy for femoroacetabular impingement with associated chondrolabral dysfunction: minimum two-year follow-up. J Bone Joint Surg Br 2009; 91-B: 16–23.

66. Sansone M, Ahlden M, Jonasson P et al. Outcome of hip arthroscopy in patients with mild to moderate osteoarthritis: a prospective study. J Hip Preserv Surg 2016; 3: 61–7.

67. Schairer WW, Nwachukwu BU, McCormick F et al. Use of hip arthroscopy and risk of conversion to total hip arthroplasty: a population-based analysis. Arthroscopy 2016; 32: 587–93.

68. Schilders E, Dimitrakopoulou A, Bismil Q et al. Arthroscopic treatment of labral tears in femoroacetabular impingement: a comparative study of refixation and resection with a minimum two-year follow-up. J Bone Joint Surg Br 2011; 93-B: 1027–32.

69. Schüttler KF, Schramm R, El-Zayat BF et al. The effect of surgeon’s learning curve: complications and outcome after hip arthroscopy. Arch Orthop Trauma Surg 2018; 138: 1415–21.

70. Sing DC, Feeley BT, Tay B et al. Age-related trends in hip arthroscopy: a large cross-sectional analysis. Arthroscopy 2015; 31: 2307–13.e2.

71. Singh PJ, O’Donnell JM. The outcome of hip arthroscopy in Australian football league players: a review of 27 hips. Arthroscopy 2010; 26: 743–9.

72. Skendzel JG, Philippon MJ, Briggs KK et al. The effect of joint space on midterm outcomes after arthroscopic hip surgery for femoroacetabular impingement. Am J Sports Med 2014; 42: 1127–33.

73. Tjong VK, Gombera MM, Kahlenberg CA et al. Isolated acetabulolasty and labral repair for combined-type femoroacetabular impingement: are we doing too much? Arthroscopy 2017; 33: 773–9.

74. Truntzer JN, Hoppe DJ, Shapiro LM et al. Complication rates for hip arthroscopy are underestimated: a population-based study. Arthroscopy 2017; 33: 1194–201.

75. Wilkin G, March G, Beaulé PE. Arthroscopic acetabular labral debridement in patients forty-five years of age or older has minimal benefit for pain and function. J Bone Joint Surg Am 2014; 96: 113–8.

76. Albers CE, Steppacher SD, Ganz R et al. Impingement adversely affects 10-year survivorship after periacetabular osteotomy for DDH. Clin Orthop Relat Res 2013; 471: 1602–14.

77. Armiger RS, Armand M, Tallroth K et al. Three-dimensional mechanical evaluation of joint contact pressure in 12 periacetabular osteotomy patients with 10-year follow-up. Acta Orthop 2009; 80: 155–61.

78. Badra MI, Anand A, Straight JJ et al. Functional outcome in adult patients following Bernese periacetabular osteotomy. Orthopedics 2008; 31: 1–7.

79. Beaulé PE, Dowding C, Parker G et al. What factors predict improvements in outcomes scores and reoperations after the Bernese periacetabular osteotomy? Clin Orthop Relat Res 2015; 473: 615–22.

80. Bernstein P, Thielemann F, Günther KP. A modification of periacetabular osteotomy using a two-incision approach. Open Orthop J 2007; 1: 13–8.
81. Bogunovic L, Hunt D, Prather H et al. Activity tolerance after periacetabular osteotomy. Am J Sports Med 2014; 42: 1791–5.
82. Burke NG, Devitt BM, Baker JF et al. Outcome of periacetabular osteotomy for the management of acetabular dysplasia: experience in an academic centre. Acta Orthop Belg 2011; 77: 33–40.
83. Clohisy JC, Ackerman J, Baca G et al. Patient-reported outcomes of periacetabular osteotomy from the prospective ANCHOR cohort study. J Bone Joint Surg Am 2017; 99: 33–41.
84. Clohisy JC, Nunley RM, Curry MC et al. Periacetabular osteotomy for the treatment of acetabular dysplasia associated with major aspherical femoral head deformities. J Bone Joint Surg Am 2007; 89: 1417–23.
85. Crockarell J, Trousdale RT, Cabanela ME et al. Early experience and results with the periacetabular osteotomy. Clin Orthop Relat Res 1999; 363: 45–53.
86. Dahl LB, Dengso K, Bang-Christiansen K et al. Intermediate to long-term results of periacetabular osteotomy for the treatment of acetabular dysplasia associated with major aspherical femoral head deformities. J Bone Joint Surg Br 2007; 89: 721–4.
87. Davey JP, Santore RF. Complications of periacetabular osteotomy. Clin Orthop Relat Res 1999; 363: 33–7.
88. Garras DN, Crowder TT, Olson SA. Medium-term results of the Bernese periacetabular osteotomy in the treatment of symptomatic developmental dysplasia of the hip. J Bone Joint Surg Br 2007; 89: 721–4.
89. Grammatopoulos G, Beale PE, Pascual-Garrido C et al. Does severity of acetabular dysplasia influence clinical outcomes after periacetabular osteotomy? A case-control study. J Arthroplasty 2018; 33: 566–70.
90. Grammatopoulos G, Wales J, Kothari A et al. What is the early/mid-term survivorship and functional outcome after Bernese periacetabular osteotomy in a pediatric surgeon practice? Clin Orthop Relat Res 2016; 474: 1216–23.
91. Hara D, Hamai S, Fukushi JJ et al. Does participation in sports affect osteoarthritic progression after periacetabular osteotomy? Am J Sports Med 2017; 45: 2468–75.
92. Hartig-Andreasen C, Troelsen A, Thillemann TM, Seballe K. What factors predict failure 4 to 12 years after periacetabular osteotomy? Clin Orthop Relat Res 2012; 470: 2978–87.
93. Hellman MD, Nepple JJ, Pascual-Garrido C et al. Acetabular focal chondral lesions are not associated with worse outcomes after periacetabular osteotomy: a matched group analyses. J Arthroplasty 2018; 33: S61–5.
94. Howie DW, Beck M, Costi K et al. Mentoring in complex surgery: minimising the learning curve complications from periacetabular osteotomy. Int Orthop 2012; 36: 921–5.
95. Isaksen KFR, Elin K, Iversen KS et al. Preoperative incipient osteoarthritis predicts failure after periacetabular osteotomy: 69 hips operated through the anterior intrapelvic approach. Hip Int 2019; 29: 516–26.
96. Ito H, Tanino H, Yamanaka Y et al. Intermediate to long-term results of periacetabular osteotomy in patients younger and older than forty years of age. J Bone Joint Surg Am 2011; 93: 1347–54.
97. Kain MS, Novais EN, Vallim C et al. Periacetabular osteotomy after failed hip arthroscopy for labral tears in patients with acetabular dysplasia. J Bone Joint Surg Am 2011; 93: 57–61.
98. Khan OH, Malviya A, Subramanian P et al. Minimally invasive periacetabular osteotomy using a modified Smith-Petersen approach: technique and early outcomes. Bone Joint J 2017; 99-B: 22–8.
99. Kim SD, Jessel R, Zurakowski D et al. Anterior delayed gadolinium-enhanced MRI of cartilage values predict joint failure after periacetabular osteotomy. Clin Orthop Relat Res 2012; 470: 3332–41.
100. Kralj M, Mavcic B, Antolic V et al. The Bernese periacetabular osteotomy: clinical, radiographic and mechanical 7-15-year follow-up of 26 hips. Acta Orthop 2005; 76: 833–40.
101. Lerch TD, Steppacher SD, Liechti EF et al. One-third of hips after periacetabular osteotomy survive 30 years with good clinical results, no progression of arthritis, or conversion to THA. Clin Orthop Relat Res 2017; 475: 1154–68.
102. Matheney T, Kim YJ, Zurakowski D et al. Intermediate to long-term results following the Bernese periacetabular osteotomy and predictors of clinical outcome. J Bone Joint Surg Am 2009; 91: 2113–23.
103. Matta JM, Stover MD, Siebenrock K. Periacetabular osteotomy through the Smith-Petersen approach. Clin Orthop Relat Res 1999; 363: 21–32.
104. Mayo KA, Trumble SJ, Mast JW. Results of periacetabular osteotomy in patients with previous surgery for hip dysplasia. Clin Orthop Relat Res 1999; 363: 73–80.
105. Millis MB, Kain M, Sierra R et al. Periacetabular osteotomy for acetabular dysplasia in patients older than 40 years: a preliminary study. Clin Orthop Relat Res 2009; 467: 2228–34.
106. Murphy SB, Mills MB. Periacetabular osteotomy without abductor dissection using direct anterior exposure. Clin Orthop Relat Res 1999; 364: 92–8.
107. Peters CL, Erickson JA, Hines JL. Early results of the Bernese periacetabular osteotomy: the learning curve at an academic medical center. J Bone Joint Surg Am 2006; 88: 1920–6.
108. Pogliacomi F, Stark A, Wallensten R. Periacetabular osteotomy. Good pain relief in symptomatic hip dysplasia, 32 patients followed for 4 years. Acta Orthop 2005; 76: 67–74.
109. Polkowksi GG, Novais EN, Kim YJ et al. Does previous reconstructive surgery influence functional improvement and deformity correction after periacetabular osteotomy? Clin Orthop Relat Res 2012; 470: 516–24.
110. Shan Chou DT, Solomon LB, Costi K et al. Structured-mentorship program for periacetabular osteotomy resulted in few complications for a low-volume pelvic surgeon. Clin Orthop Relat Res 2019; 477: 1126–34.
111. Tannast M, Pfänder G, Steppacher SD et al. Total acetabular retroversion following pelvic osteotomy: presentation, management, and outcome. Hip Int 2013; 23: 14–26.
112. Troelsen A, Elmgnaard B, Seballe K. Comparison of the minimally invasive and ilioinguinal approaches for periacetabular osteotomy: 263 single-surgeon procedures in well-defined study groups. Acta Orthop 2008; 79: 777–84.
113. Trumble SJ, Mayo KA, Mast JW. The periacetabular osteotomy. Minimum 2 year follow-up in more than 100 hips. Clin Orthop Relat Res 1999; 363: 54–63.
114. Valenzuela RG, Cabanela ME, Trousdale RT. Sexual activity, pregnancy, and childbirth after periacetabular osteotomy. Clin Orthop Relat Res 2004; 459: 146–52.
115. Wells J, Millis M, Kim YJ et al. Survivorship of the Bernese periacetabular osteotomy: what factors are associated with long-term failure? Clin Orthop Relat Res 2017; 475: 396–405.

116. Wells J, Schoenecker P, Duncan S et al. Intermediate-term hip survivorship and patient-reported outcomes of periacetabular osteotomy: the Washington University experience. J Bone Joint Surg Am 2018; 100: 218–25.

117. Zalta I, Baca G, Kim YJ et al. Complications associated with the periacetabular osteotomy: a prospective multicenter study. J Bone Joint Surg Am 2014; 96: 1967–74.

118. Zhu J, Chen X, Cui Y et al. Mid-term results of Bernese periacetabular osteotomy for developmental dysplasia of hip in middle aged patients. Int Orthop 2013; 37: 589–94.

119. Ziebarth K, Balakumar J, Domayer S et al. Bernese periacetabular osteotomy in males: is there an increased risk of femoroacetabular impingement (FAI) after Bernese periacetabular osteotomy? Clin Orthop Relat Res 2011; 469: 447–53.

120. Kowalczuk M, Yeung M, Simunovic N et al. Does femoroacetabular impingement contribute to the development of hip osteoarthritis? A systematic review. Sports Med Arthrosc 2015; 23: 174–9.

121. Palmer AJ, Malak TT, Broomfield J et al. Past and projected temporal trends in arthroscopic hip surgery in England between 2002 and 2013. BMJ Open Sport Exerc Med 2016; 2: e000082.

122. Steppacher SD, Tannast M, Ganz R et al. Mean 20-year follow-up of Bernese periacetabular osteotomy. Clin Orthop Relat Res 2008; 466: 1633–44.

123. Fukui K, Briggs KK, Trindade CA et al. Outcomes after labral repair in patients with femoroacetabular impingement and borderline dysplasia. Arthroscopy 2015; 31: 2371–9.

124. Fukui K, Trindade CA, Briggs KK et al. Arthroscopy of the hip for patients with mild to moderate developmental dysplasia of the hip and femoroacetabular impingement: outcomes following hip arthroscopy for treatment of chondrolabral damage. Bone Joint J 2015; 97-B: 1316–21.

125. Gupta A, Redmond JM, Stake CE et al. Does primary hip arthroscopy result in improved clinical outcomes? 2-year clinical follow-up on a mixed group of 738 consecutive primary hip arthroscopies performed at a high-volume referral center. Am J Sports Med 2016; 44: 74–82.

126. Redmond JM, Gupta A, Dunne K et al. What factors predict conversion to THA after arthroscopy? Clin Orthop Relat Res 2017; 475: 2538–45.

127. Redmond JM, Gupta A, Cregar WM et al. Arthroscopic treatment of labral tears in patients aged 60 years or older. Arthroscopy 2015; 31: 1921–7.

128. Byrd JW, Jones KS. Prospective analysis of hip arthroscopy with 10-year follow-up. Clin Orthop Relat Res 2010; 468: 741–6.

129. Philippon MJ, Schroder E Souza BG, Briggs KK. Hip arthroscopy for femoroacetabular impingement in patients aged 50 years or older. Arthroscopy 2012; 28: 59–65.

130. Domb BG, Gui C, Lodhia P. How much arthritis is too much for hip arthroscopy: a systematic review. Arthroscopy 2015; 31: S20–9.

131. Kemp JL, MacDonald D, Collins NJ et al. Hip arthroscopy in the setting of hip osteoarthritis: systematic review of outcomes and progression to hip arthroplasty. Clin Orthop Relat Res 2015; 473: 1055–73.

132. Clohisy JC, Schutz AL, St John L et al. Periacetabular osteotomy: a systematic literature review. Clin Orthop Relat Res 2009; 467: 2041–52.

133. Griffin DR, Dickenson EJ, Wall PD et al. Hip arthroscopy versus best conservative care for the treatment of femoroacetabular impingement syndrome (UK FASHIoN): a multicentre randomised controlled trial. Lancet 2018; 391: 2225–35.

134. Palmer A, Ayyar-Gupta V, Dutton S et al. Protocol for the femoroacetabular impingement trial (FAIT) a multi-centre randomised controlled trial comparing surgical and non-surgical management of femoroacetabular impingement. 2014; 3: 321–7.