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Review article

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

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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 sequalae 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 procedures, were utilizing HA to evaluate THA, not using conversion to THA as an endpoint, utilizing HA to evaluate or treat symptoms post-PAO in the setting of hip dysplasia or papers that looked at arthroscopic use of novel stem cell/biological therapies. Data published on open management of FAI surgery were not included as the authors felt that the literature was too sparse and heterogeneous to include, difficult to compare results due to lack of standardization and because the trend in the literature is towards arthroscopic management of FAI. Search strategies were reviewed by the lead author and was secondarily reviewed by a separate author to ensure that all relevant studies were included and to remove selection bias. If there was a discrepancy or query as to whether a paper should be included this a third opinion from one of the senior authors was sought.

Data extraction

The selected articles underwent duplicate removal both electronically and manually and the subsequent articles were exported to Endnote™ reference manager. Following this, abstracts were reviewed in line with the inclusion/exclusion criteria. The final number of articles remaining were then assessed via full-text review and data were extracted and placed into a spreadsheet in Microsoft Excel™ based on a pre-determined set of variables, which included, author, year, level of evidence, MINORS score, number of hips included, mean age, number of hips converted to THA, mean (or median) follow-up (months), mean time to conversion (months).

Data analysis and synthesis

Papers were attributed a 'level of evidence' based on the 'Oxford Centre for Evidenced-Based Medicine—levels of evidence' [12]—this did not always correlate with the authors self-declaration of level of evidence.

Papers were also graded according to MINORS score [13], where there was any ambiguity, uncertainty or insufficient information for attributing points, for the MINORS scoring for each criteria, points were not given.

Statistical analysis

Statistical analysis on categorical data was performed using Chi-squared test and for continuous data, student *t*-test was used. Confidence intervals were obtained by using binomial distribution calculations. Data were analysed using Minitab® 18.1 statistical analysis software. A P values of <0.05 was considered statistically significant. Data were sub-analysed, when considering risk factors for conversion to THA, if papers presented sufficient raw data allowing for such sub-analysis.

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 I. 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%

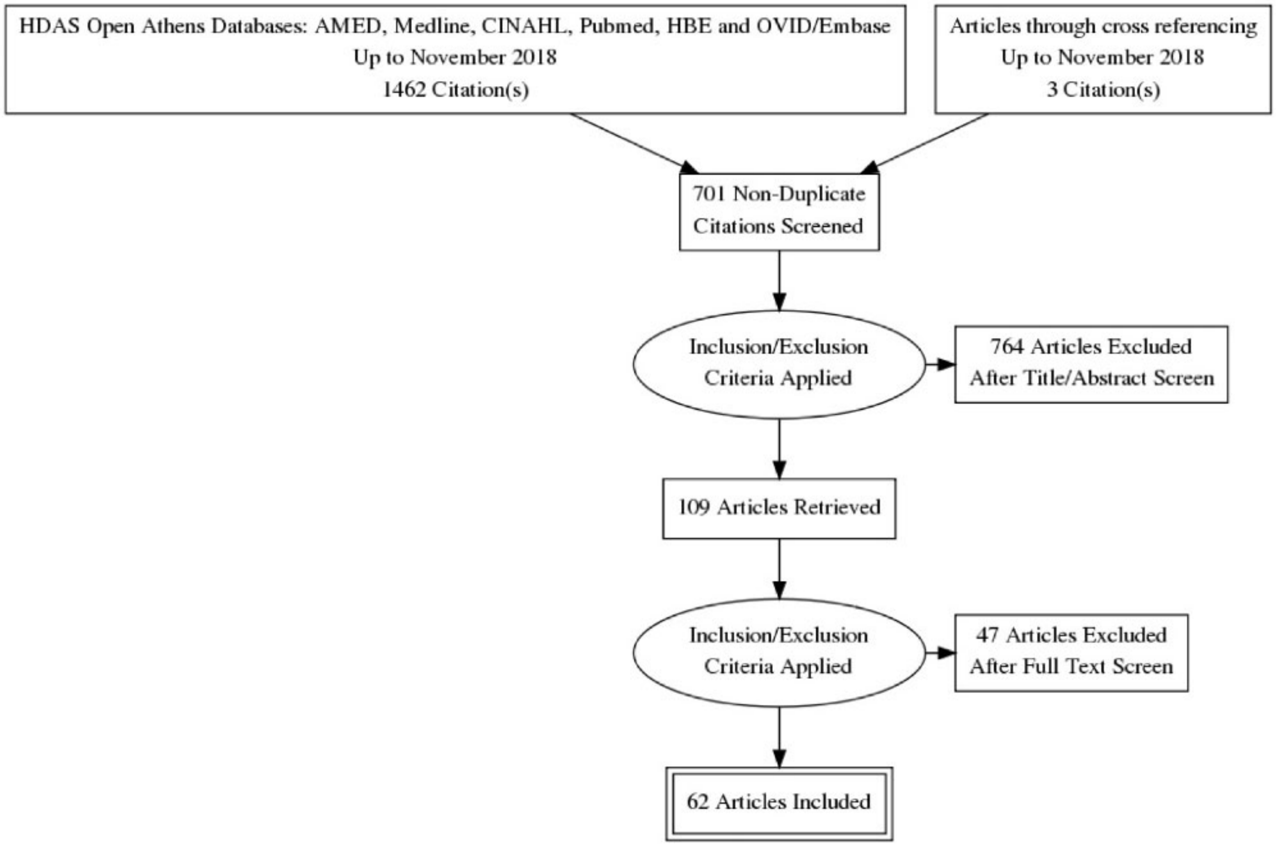

Fig. 1. HA search: PRISMA flowchart.

[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].

Table I. Results for HA

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
Philppon *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[a]
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

(continued)

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

(continued)

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.

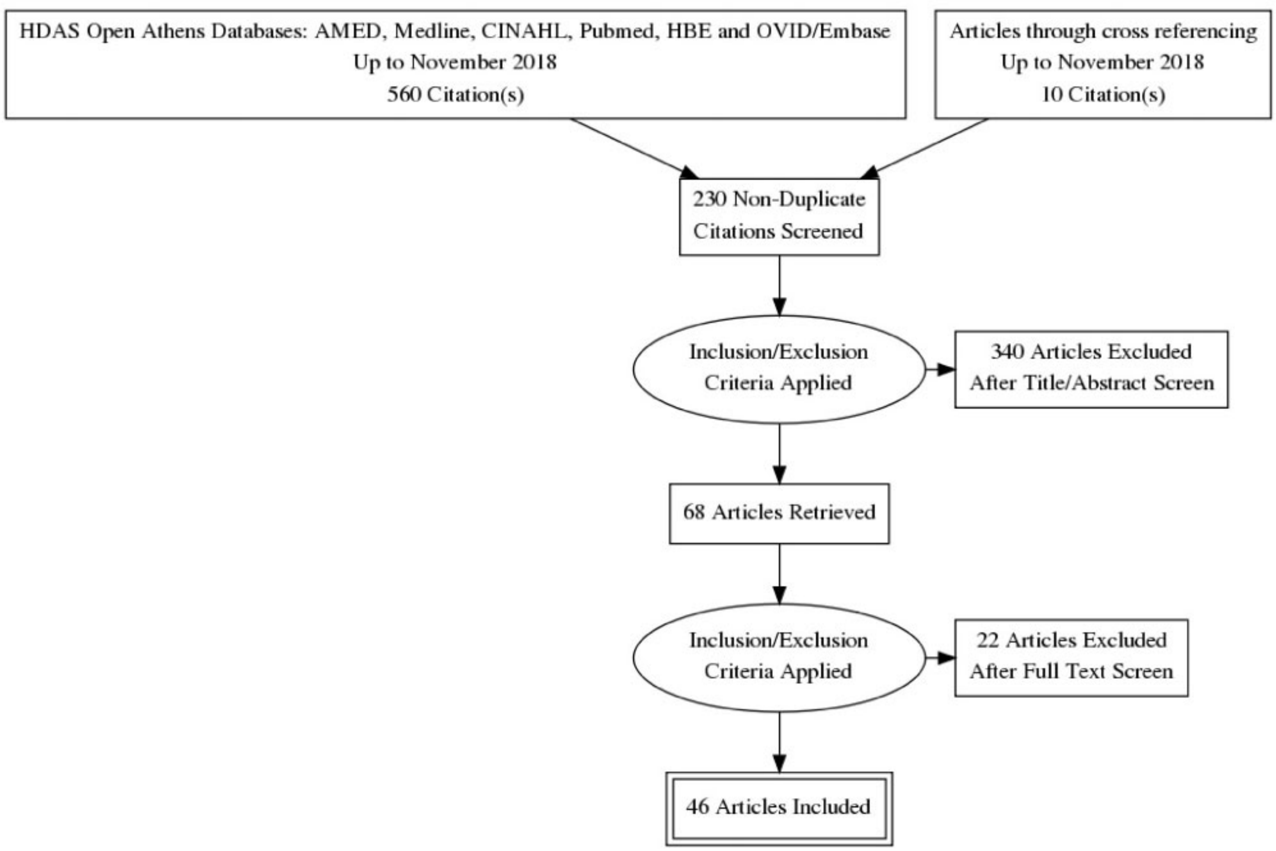

Fig. 2. PAO search: PRISMA flowchart.

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 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

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[a]	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[a]	18/24	263	31/35	15	• 58.8–110.4 • 12.0–48.8 • 12.0–58.8	52.8/26
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[a]	16/24	17/34	31	3	56.4/31.2	169.2[a]
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)

Table II. (continued)

Author	*Year*	*Level of evidence*	*MINORS score*	*Number of hips*	*Mean age*	*Hips converted*	*Mean/median follow-up (months)*	*Mean time to conversion (months)*
Beaulé *et al.*	2014	4	10	72	32	1	60	86
Bogunovic *et al.*	2014	4	8	39	25	1	33	27
Dahl *et al.*	2014	4	12	122	31	11	84	54
Zaltz *et al.*	2014	4	10	205	25.4	1	14	36
Grammatopoulos *et al.*	2015	4	10	66	25	4	96	94
Wells *et al.*	2016	4	8	121	26	26	216	108
Clohisy *et al.*	2017	4	12	391	25.4	3	31.2	Not stated
Hara *et al.*	2017	4	8	183	42	4	100	Not stated
Khan *et al.*	2017	4	10	166	32	2	33.6	20
Lerch *et al.*	2017	4	9	75	29	42	348	192
Shan Chou *et al.*	2018	4	10	85	26	6	60	45.5
Grammatopoulus *et al.*	2018	4	14	244	26	3	48	Not stated
Hamai *et al.*	2018	4	9	46	47.5	14	202.8	108
Hellman *et al.*	2018	3[a]	10	56	31.08/28.61	0	36.0/50.41	NA
Isaksen *et al.*	2018	4	10	69	32	9	88.8	88.8
Navid *et al.*	2018	4	9	302	32.7	54	134.4	Not stated
Wells *et al.*	2018	4	8	154	26	8	123.6	81.6

[a]Value calculated from data.

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. 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 9.39–8.52%]) 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 52.28–20.28%]) 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 re-orient 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 Sohatee - 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.

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