REVIEW ARTICLE

Functional outcomes after Total Hip Arthroplasty among patients aged 30 years or less: A Systematic Review and Meta-analysis

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ABSTRACT

Introduction: Total hip arthroplasty (THA) is the treatment of choice in patients aged <30 yearssuffering from end-stage hip arthropathy. **Aim:** This systematic review aimed to determine the improvement in the functional outcomes among young patients (<30 years of age) who underwent THA. **Methods:**We searched a total of 7 electronic databases including PubMed, Embase, and Cochrane central using a comprehensive search strategy to retrieve the relevant articles. We undertook a meta-analysis using a random effect model to assess whether THA in patients aged less than 30 years resulted in significant functional improvement. The primary outcome of the study was an increase (change before & after THA) in Harris Hip Score. **Results:** A total of 17 articles (all case series) collectively representing the outcome among 751 patients (and 945 hips) were included in the review. The mean age of patients was 24.3 (range 12-30) years. The most common underlying indication for THA was Avascular necrosis (AVN) (39%). The mean difference between the HHS, at the last, follow-up visit and the pre-operative HHS was 42 (95% CI 37- 44; p-value <0.00001). Among 945 hips, 73 (7.2%) required revision. The annualized rate of revision was 0.86%.**Conclusion:** THA of all types resulted in significant functional improvement among young patients.

INTRODUCTION

Total hip arthroplasty (THA) is an effective treatment of end-stage hip osteoarthritis (OA) to restore patients' quality of life (QOL)(1). THA is indicated for patients who failed to respond to non-surgical management options such as pharmaceutical treatments, self-management, patient education, acupuncture, exercise, physical therapy, or manual therapy(1). THA involves the replacement of a damaged hip joint with an artificial hip prosthesis consisting of an acetabular cup (with or without shell) a femoral stem, and a femoral head. Following THA, the majority of patients experience reductions in pain, improvements in function and better health-related quality of life(2). However, not all patients achieve the same level of functional improvement after THA. Specifically, more than 30% of patients undergoing THA report moderate-to-severe activity limitations 2 years post-THA(3–5). It is unclear which factors are associated with these limitations in function.Despite the widely recognized success of the THA, the incidence of revision THA is on the rise(3–5). Aseptic loosening, recurrent dislocation, infection, or periprosthetic fracture are the primary reasons attributed to this increased rate of revision THA. Patients report high expectations for improvements in pain, function, and QOL even after revision surgery. The use of patient-reported outcome measures (PROMs) to evaluate the clinical effect of arthroplasty procedures yields unique insight into the patient's actual and perceived physical benefits of revision THA(6–8).

The functional outcome, quality of life, and patients reported outcome measures are influenced by the age

of the patients(6–8). This is secondary to the indications for the THA, expected outcome, and lifestyle of the patients. The benefits of total hip arthroplasty (THA) in the mature population have been well documented in the literature(9). However, the functional outcome of THA among patients aged 30 or less, has never been the focus of exclusive research(10,11). The indications for THA among the young population are very diverse and different from those in older patients and include a range of congenital, developmental and acquired conditions which result in end-stage hip arthritis, such as avascular necrosis (AVN), juvenile rheumatoid arthritis (JRA), developmental dysplasia of the hip, slipped upper femoral epiphysis and post septic chondrolysis(10,11). These cases are often technically challenging due to the deformity encountered, muscle wasting, scarring and retained implants from previous surgery. THA offers these young patients the opportunity to attain excellent levels of pain relief and enhanced function, albeit with a greater risk of revision within their lifetime. Historically it has been this potential for earlier failure and multiple revisions that have discouraged surgeons from offering THA as a treatment option for patients aged 30 or less(10,11).
For young patients, functional outcome is just as, if not more, important than survivorship as many young people want to return to education, work, normal parenting duties, sport and physical social activities. Currently, there are no large series to answer questions concerning functional outcomes and survivorship and as yet the arthroplasty registries do not report patient outcome measures. Therefore, we have designed a systematic review and conducted a meta-analysis to assess whether THA in patients aged 30 years or less provides significant and sustained functional improvement.

MATERIAL AND METHODS

This systematic review fully adhered to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines(12). The meta-analysis was conducted using the methods described by the Cochrane Collaboration in their Handbook for Systematic Reviews of Interventions,6th edition(13). Review Manager software version 6.2 (RevMan) was used to conduct the meta-analysis and to produce the resultant forest plot figures(14). This meta-analysis did not involve direct contact with individual patients; therefore, no ethics approval was needed. The review was retrospectively registered with Prospero (https://www.crd.york.ac.uk/prospero/).

PRIMARY OBJECTIVE

To determine, based on the review of evidence from all types of epidemiological studies, the functional outcome among patients aged thirty years or less after total hip arthroplasty performed for any indication.

PICOT FRAMEWORK

- **Population:** Patients aged 30 years or less of all genders.
- **Intervention:** Total Hip Arthroplasty conducted for any indication
- **Control:** Not applicable
- **Outcome:** Functional outcome: Harris Hip Score before and after THA.
- **Type of studies:**All published studies reporting the functional outcome after total hip arthroplasty among patients aged 30 years or younger. Only peer-reviewed publications were considered for inclusion. Grey literature was not searched. Unpublished data were not sought, however, authors of published studies were contacted to clarify or provide additional information.

EXCLUSION CRITERIA

1. Studies not reporting any type of functional outcomes
2. Studies reporting non-surgical interventions
3. Studies not reporting outcomes among patients aged less than 30 years.
4. Studies with incomplete data.

SEARCH STRATEGY

An electronic search strategy was developed for each of the following databases searched to complete this systematic review: PubMed, Embase, Cochrane Musculoskeletal Group Trials Register, the Cochrane Controlled Trials Register (CENTRAL/ CCTR), the Health Technology Assessment Database (HTA), and the Database of Abstracts of Reviews of Effectiveness (DARE). We reviewed the Musculoskeletal Review Group MeSH search terms for selecting the most appropriate and recommended terms and phrases for building a comprehensive search strategy. Examples of the keywords were: “Arthroplasty, Replacement, Hip”, ‘total hip replacement’, ‘total hip arthroplasty, ‘THR’, ‘THA’, ‘young adult’, ‘adolescent’, ‘child’, ‘teen*’, ‘paediatric’, ‘harris’ and ‘HHS’ etc. A trained medical librarian was consulted to develop an optimal search strategy. Search terms that were used are shown in Appendix 1.

PERIOD OF SEARCH

The search covered the studies published from the inception of the database to June 2022.

LANGUAGE

Studies published in English language only.

RESULTS OF ELECTRONIC SEARCH

The reference generated from the electronic search were imported into the Mendeley citation software. Thereafter, the results of the search strategy from all the databases were merged. Citation management software (Mendeley) was used to remove duplicate results.

STUDY SELECTION

Two reviewers independently assessed all potential abstracts and published reports that were identified by the literature search. If there was a controversy between the reviewers, we asked a senior reviewer to make a decision. The consensus was reached through discussion of any disagreements. Reasons for excluded studies were noted. The reviewers were not blinded to authors, institutions or journals of the publication.

DATA EXTRACTION

Each reviewer extracted data independently using pre-designed standardized data abstraction forms created using Microsoft Excel and Revman. Discrepancies were resolved by a consensus of the two reviewers. Two reviewers independently extracted the following information: first author name and publication year, country, patients' general characteristics,number of patients treated; the number of hips treated; patient age at operation; patient gender; underlying diagnosis; stem and cup fixation method (uncemented or cemented); bearing surfaces; mean follow up with range and standard deviation; mean preoperative HHS with range and standard deviation; HHS at last follow-up with range, standard deviation and p-value for significance versus preoperative score; the number of hips revised; deaths and other complications, and follow-up duration.

DATA SYNTHESIS AND ANALYSIS

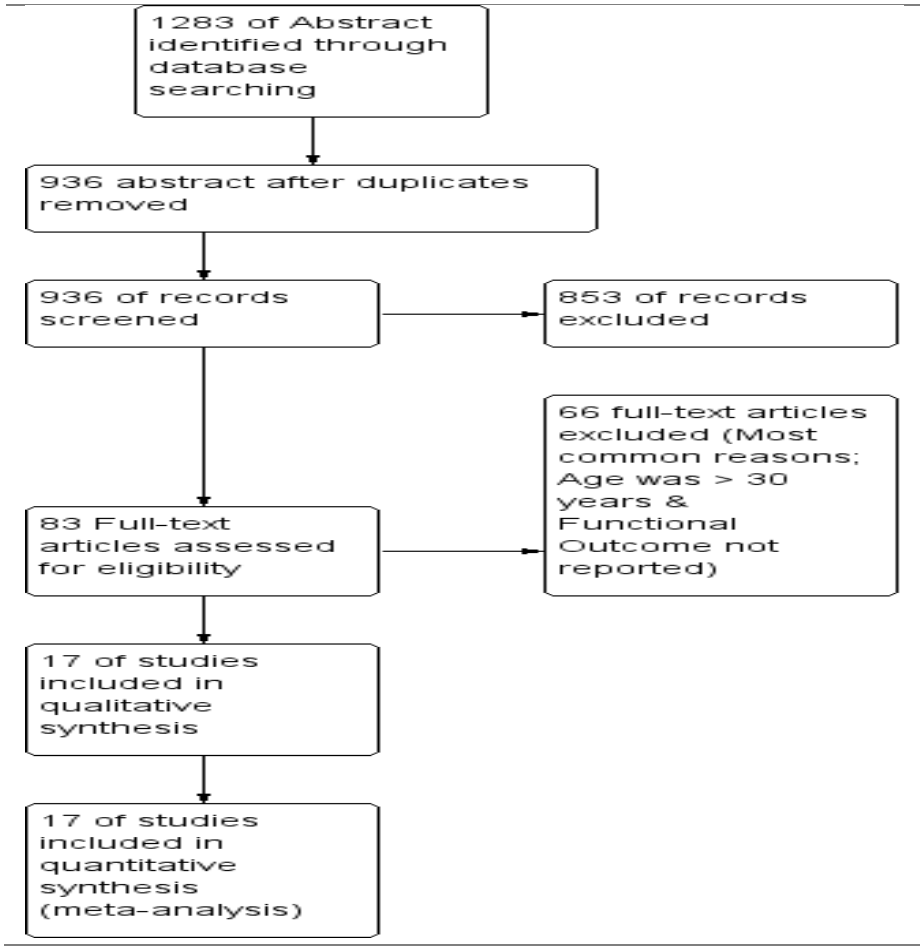
For each study, relative risks and 95% confidence limits were calculated for dichotomous outcomes, and weighted mean differences and 95% confidence limits were calculated for continuous outcomes. Meta-analyses were conducted with a fixed effects model. Where there was statistical evidence of heterogeneity a random effects model was used. Continuous outcomes (Harris hip score) were expressed as the weighted mean differences (WMD) with 95% confidence intervals (CIs). Statistical analysis was performed using Stata software, version 17.0 (Stata Corp., College Station, TX, USA). To assess the heterogeneity, the I^2 index and corresponding p-value were calculated. When I^2 was less than 50%, there was low heterogeneity; otherwise, there was a high heterogeneity. Publication bias was visually assessed using funnel plots (effect size was symmetry = no publication bias) and was quantitatively assessed using Begg's test ($p > 0.05$ = no publication bias).

RESULTS

RESULT OF SEARCH STRATEGY

The electronic search strategy designed for this study yielded a total of 1283 abstracts/studiesfrom the selected databases. Then, all the abstracts were imported into Mendeley software, thereafter, 347 duplicate abstracts were removed (Figure 1). A total of 936 shortlisted abstracts were reviewed by reading thecontent of the abstract using the selection criteria for the review. After the first stage of screening, 853 abstracts were excluded. The most common reasons for exclusion were as follows: included older patients, did not measurefunctional outcome etc. A total of 83 abstracts were included for full-text review. After a full-text review and 66 papers were removed according to the inclusion and exclusion criteria. The most common reasons for exclusion were as follows: there was no separate date for patients younger than 30 years, included older patients, and did not report the desired functional outcome.

Figure 1: PRISMA Flow diagram



STUDY CHARACTERISTICS

All 17 studies were case series (therapeutic studies, levelIV evidence) and were published in peer-review journalsbetween1981 and 2020. The total sample sizes among the included studies were 751 patients: ranging from a minimum of 5 patients (Bartoníček et al.)(15) to 96 patients (Kim et al. 2012)(16). These 751 patients represented a total of 945 hips; ranging from a minimum of 5 to 127 hips (see Table 1). A total of 388 patients (51.7%) were male and 363 patients (48.3%) were female. The mean age of patients was 24.3 (range 12-30) years. The most common underlyingdiagnoses in the decreasing order of frequency were Avascular necrosis (AVN) (39%), developmental dysplasiaof the hip (15%), JRA (14%), posttraumatic arthritis (7%),childhood hip sepsis (6%), Legg-Calvé-Perthes disease (4%),slipped upper femoral epiphysis (3%), multiple epiphysealdysplasias(2%) and others (10%).

Most of the included 17 studies had significant diversity concerning the indications for hip arthroplasty: 13 studies included patients with a mixed aetiology for hiparthropathy and only 4 remaining studies focused on THAin patients with a single diagnosis (JRA, AVN and post-traumatic hip arthropathy). Most of the included studies used several variants of hip implants:14 studies used uncementedacetabular components in every case; 2 studiescombined cemented and uncemented acetabular components and 1 paper published in 1981used only cemented acetabular and femoral components.In addition to clinical outcomes measured with pre- and postoperative HHS,most studies also included radiological assessments, complications of surgery, mortality and implantsurvival.

Table 1: characteristics of the included studies

Author	Country	Year	Sample size	Hips
Agarwal	UK	2020	78	101
Bartoníček	Czech Republic	2012	5	5
Bilsel	Turkey	2008	23	37
Byun	South Korea	2011	41	56
Chandler	USA	1981	29	33

Clohisy	USA	2010	88	102
Costa	USA	2012	40	53
Dudkiewicz	Isreal	2003	56	69
Finkbone	USA	2012	19	24
Kamath	USA	2012	18	21
Kim	South Korea	2012	96	127
Kim	South Korea	2013	50	60
Mardani-Kivi	Iran	2013	41	46
Pakos	Greece	2014	30	45
Restrepo	USA	2008	25	35
Wade	India	2019	50	56
Yoon	South Korea	2012	62	75

Table 2: Age and the duration of follow up (in years)

Author	Age	Range of Age	Follow up	Range of Follow up
Agarwal(10)	25	16-30	12.5	5-22
Bartoníček(15)	19.0	15-26	8.2	5-10
Bilsel(17)	22.3	17-30	10.5	4-16.8
Byun(18)	25.	16-29	7.7	6-8.5
Chandler(17)	23	14-30	5.6	4.8 – 7
Clohisy(19)	20	12-25	5.1	1.9 16.4
Costa(20)	20	13-30	4.5	2 – 7.3
Dudkiewicz(21)	23.2	14-29	7.4	2.1 -23.0
Finkbone(22)	16.4	12-20	4.3	2.1 – 3.0
Kamath(23)	18	13-20	4.1	2.1 – 7.4
Kim(24)	24.2	19-30	14.6	10-16
Kim(25)	28.7	21-29	10.8	10-12
Mardani-Kivi(26)	24.4	17-30	5.2	4.3 – 6.8
Pakos(27)	23.3	13-29	9.6	2-22
Restrepo(17)	17.6 (13-20)	13-20	6.6	4.2 – 10
Wade(28)	21.7	18-30	5	3-6.1
Yoon(29)	24.0 (18-30)	18-30	11.5	10 – 13.5

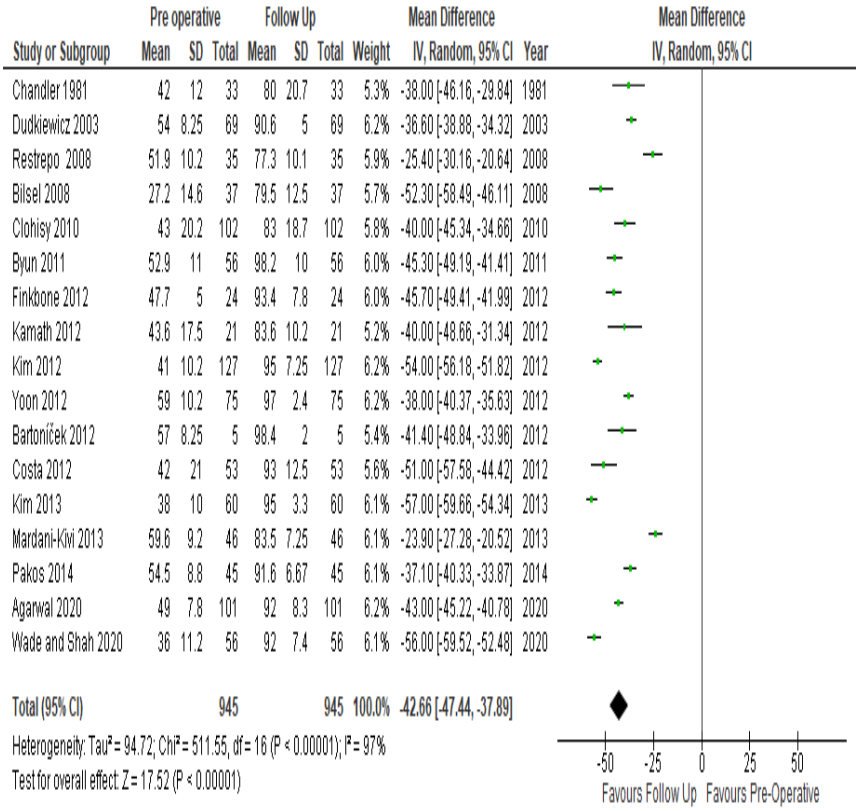
Table 3 illustrates the functional outcome in terms of Harris Hip score before and after the hip arthroplasty. Most studies followed participants at frequent intervals. The postoperative follow-up score shown in the second last column of table 3 shows the HHS at the last follow-up visit. The mean duration of follow-up was 8.9 (range 2-22) years.

Table 3: HHS score before and after arthroplasty

Author	Type	Pre-op Mean HHS	HHSfinal followup	Revisions
Agarwal	Cementless	49 (39-62)	92 (82-98)	19
Bartoníček	Cementless	57.0 (33.0-65.0)	98.4 (98-99)	0
Bilsel	Hybrid	27.2 (11-69)	79.5 (37-87)	3
Byun	Ceramic-On-Ceramic	52.9 (37-59)	98.2 (80-100)	0
Chandler	Cementless	42.0 (13-60)	80.7 (17-100)	5
Clohisy	Cementless	43.0 (5-86)	83.0 (26-100)	7
Costa	Cementless	42.0 (10-94)	93.0 (47-100)	2
Dudkiewicz	Ceramic	54.0 (31-67)	90.6 (79-100)	14
Finkbone	Ceramic	47.7 (37-59)	93.4 (66-100)	1
Kamath	alternative-bearing	43.6 (11-83)	83.6 (63-100)	1
Kim	Cementless	41.0 (9-53)	95.0 (71-100)	1
Kim	Cementless	38.0 (6-45)	95.0 (85-100)	0
Mardani-Kivi	Cementless metal–polyethylene	59.6 (41-76)	83.5 (71-97)	0
Pakos	Ceramic on polyethylene design	54.5 (47-63)	91.6 (84-98)	11
Restrepo	Cementless	51.9 (40-82)	77.3 (60-99)	2
Wade	Uncemented	36 (31-47)	92 (83-97)	6

Yoon	alumina-on-alumina	59.0 (40-83)	97.0 (93-100)	1

Figure 2: Forest plot showing mean Preoperative and Postoperative Harris Hip Scores for all studies at final follow-up after THA.



The findings of the meta-analysis are presented in figure 2. As can be seen from the figure, hip arthroplasty in every study included in the metanalysis reported a significant improvement in functional outcome (increase in HHS after surgery). The mean difference between the post (at last follow-up visit) and the pre-operative HHS was 42 (95% CI 37- 44; p-value <0.00001).

Table 4: Pre and Postoperative difference in HHS			
Type of Implant	**Delta HHS**	**95% CI**	**P-value**
Overall	42.66	37.89 – 47.44	< 0.0001
Uncemented THA	47.6	39.5-54.8	<0.0001
All fixation Hard-ons-oft bearing surfaces	43.5	36.7 – 51.2	< 0.0001
All Fixation ceramic-on-ceramic bearing Surfaces	48.6	36.7 – 58.9	<0.0001
Uncemented Hard-on-soft bearing surfaces	44.6	39.3 – 50.2	< 0.0001
Uncemented Ceramic-on-ceramic bearing surfaces	48.9	41.3 – 55.2	<0.0001

Table 5: Hip revision rate by the type of Implant.					
Subgroup	**Hips (n)**	**Mean Follow Up (years)**	**number of revisions (n)**	**Revision (%)**	**Annualised revision rate (%/year)**
Cemented, hard-on-soft*	33	6.6	5	15.15	2.3
All fixation, hard-on-soft	345	8.3	30	8.69	1.05

bearings					
Uncemented, hard-on-soft bearings	203	7.9	9	4.4	0.56
Uncemented THA, ball bearings	488	9.2	6	1.2	0.13
All fixation, ceramic-on-ceramic bearings	307	11.3	14	4.6	0.35
Uncemented, ceramic-on-ceramic bearings	281	11.8	9	3.2	0.27
All patients	945	8.9	73	7.2	0.86

Among the studies included for review out of a total of 945 hips replaced, 73 (see table 3)hips(7.2%) required revision. The annualized rate of revision was 0.86%.The annual revision rate was the lowest for uncemented THA.

DISCUSSION

Several factors determining the outcome of THA among young and old are diametrically opposite. These factors were the predominant reasons for initial hesitancy shown by several orthopedic surgeons while recommending THA among young patients. These factors include life expectancy and longevity. The postoperative expected life expectancy of a geriatric patient is significantly shorter than a young patient.Secondly, the range and degree of physical activity and mobility among young patients is far more extreme than geriatric and adult patients. Lastly, several young people will have a growth spurt. All these factors determinethe success of THA and revision rate of after initial treatment.

A total of 17 studies were included in this review. Each of the 17 included study reported an increase in HHS score after THA. Further, the improvement in HHS score was maintained over a very long period of follow-up. The difference in the HHS preoperatively and at the last follow up was statistically significant in all 17 included studies. The increase in HHS score ranged from a minimum of 23 points (Mardani-Kivi et al., 2013(26)) to 57 points (Kim et al. 2013(24)). Moreover, the included 17 studies enrolled young patients aged from a minimum of 12 years to a maximum of 30 years and participants underwent THA for a variety of indications. Lastly, all existing types of hip implants were used for treating young patients.

All thefindings discussed above have significant implications for recommending THA for various hip pathologies among young patients with THA. Firstly, the findings of this review suggest that THA can be evenoffered to a very young patients for improving the functional outcome irrespective to the pathology and type of implants. The degree of functional improvement and the revision requirement later in life may vary from pathology to pathology and type of implants, however, a significant improvement in the functional outcome can be assured in every patient. The functional outcome in the present study was measured using the HHS. The HHS has been widely used for a long period of time thus, its applicability is proven in all population groups. Secondly, the contruct validity and applicability means that results are reliable and can be replicable under Indian settings. However, in recent years, a limitation of HHS has been identified by several researchers. The HHS has been criticized to have a 'ceiling effect' i.e., a patient may score high during assessment yet still be having some functional deficit. Nevertheless, it is still the most widely used parameter for assessing the functional outcome after THS. Hence, for this review we relied predominantly on HHS to measure the outcome of THA.

Over the years several studies and reviews have published on similar topic. Some of the findings of this latest review were significantly different from their findings. These differences could be explained by following reasons(10,30–35). The advancement in the technology of hip implants have made them more resilient for wear and tear. Secondly, the experience of surgeons increases their confidence for performing THA among young patients. Lastly, patients included in studies published earlier had different spectrum of pathologies that those published in the last decade. For example, the systematic review by Adelanietal**,** had more than one third of patients diagnosed with JRA(36). In their review, the overall implanter vision rate in their study was19.6%.Geeatal., also ranked JRA as the most common diagnosis in their systematic review and reported a combined revision rate of 19.9% for the acetabulum(37). Our finding are very similar to the review published by Walker et al about 7 years ago(38). We have also included 3 newer studies published after the review by Walker et al. was published.

Most of the studies included in the review were conducted in western countries. Republic of South Korea was the only Asian country to contribute more than one study in the review. In the absence of regular published data from India or other south Asian countries it is difficult to suggest how our findings matches with the outcome among patients who underwent THA at young age.

From the gathered evidence uncemented acetabular component had the lowest revision rate. These findings can already be observed in the practice of orthopedic surgery as most of the advance center that perform THA in young patients universally prescribes uncemented acetabular component (mostly ceramic) unless contraindicated. However, the evidence concerning the

success of the material for fixing acetabular component with the femoral stem less certain. Several authors of the included studies have reported dissatisfaction with the cementedfemoralstemsin youngpatients secondary to higher revision rate and less than expected improvement in HHS postoperatively. Thus, studies published after 2010 have increasingly reported using all-uncemented fixationinyoungerpatients. Moreover, several studies that did not exclusively enrolled young patients have also reported that uncemeted ceramic implants (both acetabula and stem component) had very high survival rate and excellent functional outcome over long duration of follow up.

Based on the results of the sub-group analysis, we observed that various permutation and combinations of implant component had different functional outcome and survival rate. The results of the sub-group analysis suggests that all-uncemented THA smayout- perform hybrid, reverse hybrid and cemented THA interms of both survivors hip and functional outcome. Bearing surfaces were divided into hard-on-soft and CoC based on the different modes of wear in these two bearing combinations and therefore he likely mechan is mof implant failure. Hard-on-soft bearings produce polyethylene particulatedebris, which incite sosteolysis via the RANKlig and path- way. Incontrast, ceramic weard ebrisis biologically inert and is producedintiny quantities compared with polyethylene debris. It is therefore uncle ar how these bearings will failin the long-term although they remain at risk of fracture.

The results presented here appear to suggest that CoC bearings outperform hard-on-soft couples interm so fim provement in the HHS, revision rate and loosening. However, it is difficult to compare the set wosub-groups despitesimi- larcohortsizes. There were 65(21.5%) cemented ups in the hard-on-soft group versusal luncemented cups in the ceramic-on-ceramic group. There were also a greater proportion of uncemented stemsin the ceramic-on-ceramicgroupversus thehard-on-softgroup(99.3%vs.74.9%).Thehard-on-soft groupalsocontainsahistoricstudywithall-cemented hips and another study of THA in 23 patients with JRA in which there were 23c emented cups out of 37 THAs. These 2 studies could easily introducebias, and it is very plausible that the apparent better HHS and revision rat esseen in the ceramic- on-ceramic group were therefore attribute able to uncemented fixation. When studies that only contained uncemented THAs were analysed there was no significant differences between HHS and revision in patients with CoC bearings versus those with hard-on-soft articulations.

Overall, it is not possible to demonstrate statistically significant superiority of uncemented fixation or CoC bearings in terms of HHS improvement or survivorship. However, there is atrend which suggests that these 2 in combination may offer the best outcome, with the largest weighted mean difference in HHS and the lowest revision rates seen in the uncemented, ceramic-on-ceramic subgroup. The largest study in this meta-analysis included 127 uncemented THAs with CoC bearings and yielded a 54-point improvementin HHS and only 1 revision at 14.6 years follow-up. Only a randomized trial between cemented and uncemented stems and hard-on-soft versus CoC bearings will beable to determine superiority with confidence, and only for the selected implant combinations. We have performed a power calculation at the 80% beta errorlevel and 5% alpha errorleveland such a study would require 57 subjects in each arm, and would need to run prospectively over 8 years to detecta 5-point difference in mean HHS. To detecta1% difference in mid-termrevision rate 315 subjects in each arm would need to be followed up over 8 years. Clearly such large-scale studies in this agerange are beyond the scope of most institutions. Only registry data in years to come may be able to answer the question of optimum fixation and bearing choice for this challenging patient group.

SUMMARY

THA in young patients provides good relief of symptoms and allows an improvement in functional scores irrespective of implant choice or fixation technique. Improvements in HHS and rates of revision are similar to the excellent results seen in the more elderly population, acontrary finding to all previously published reviews, which report much higher revision rates and poor erfunctional out come in the very young patient population. The implication is that utilizing modern implants, techniques and bearing sur- faces yields good clinical outcomes. There is currently in sufficient data to draw robust clusions about the optimum fixation and bearing combination. Long-term studies and registry data are necessary to confirm the superiority of specific implants, bearing and fixation combinations.

REFERENCES

1. Piuzzi NS, Slullitel PAI, Bertona A, Oñativia IJ, Albergo I, Zanotti G, et al. Hip arthroscopy in osteoarthritis: A systematic review of the literature. HIP Int. 2016 Jan 1;26(1):8–14.
2. Blackburn J, Lim D, Harrowell I, Parry MC, Blom AW, Whitehouse MR. Posterior approach to optimise patient-reported outcome from revision hip arthroplasty. HIP Int. 2017 Mar 1;27(2):175–9.
3. Malahias MA, Gu A, Richardson SS, De Martino I, Sculco PK, McLawhorn AS. Hip arthroscopy for hip osteoarthritis is associated with increased risk for revision after total hip arthroplasty. HIP Int. 2021 Sep 1;31(5):656–62.
4. Hulsbæk S, Larsen RF, Troelsen A. Predictors of not regaining basic mobility after hip fracture surgery. Disabil
5. Kondo A, Hagino H, Zierler BK. Determinants of ambulatory ability after hip fracture surgery in Japan and the USA. Nurs Heal Sci. 2010 Sep;12(3):336–44.
6. Ostendorf M, van Stel HF, Buskens E, Schrijvers AJP, Marting LN, Verbout AJ, et al. Patient-reported outcome in total hip replacement. A comparison of five instruments of health status. J Bone Jt Surg - Ser B. 2004 Aug;86(6):801–8.
7. Stasi S, Papathanasiou G, Diochnou A, Polikreti B, Chalimourdas A, Macheras GA. Modified

Harris Hip Score as patient-reported outcome measure in osteoarthritic patients: psychometric properties of the Greek version. [cited 2022 Dec 29]; Available from: https://doi.org/10.1177/1120700020901682

8. Cook MJ, Lunt M, Ashcroft DM, Board T, O'Neill TW. The impact of frailty on patient-reported outcomes following hip and knee arthroplasty. Age Ageing [Internet]. 2022 Dec 5 [cited 2022 Dec 29];51(12). Available from: https://academic.oup.com/ageing/article/doi/10.1093/ageing/afac288/6936399
9. Shapira J, Chen SL, Rosinsky PJ, Maldonado DR, Lall AC, Domb BG. Outcomes of outpatient total hip arthroplasty: a systematic review. HIP Int. 2021 Jan 1;31(1):4–11.
10. Agrawal Y, Kerry RM, Stockley I, Hamer AJ. Review of total hip arthroplasty in patients younger than 30 years: mid- to long-term results. HIP Int. 2021 Jul 1;31(4):533–41.
11. Mei XY, Gong YJ, Safir O, Gross A, Kuzyk P. Long-term outcomes of total hip arthroplasty in patients younger than 55 years: A systematic review of the contemporary literature. Can J Surg. 2019;62(4):249–58.
12. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane handbook for systematic reviews of interventions. John Wiley & Sons; 2019.
13. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. Cochrane handbook for systematic reviews of interventions [Internet]. Cochrane Handbook for Systematic Reviews of Interventions. 2019 [cited 2023 Mar 21]. 1–694 p. Available from: https://training.cochrane.org/handbook#how-to-access
14. Cochrane. RevMan 5 download | Cochrane Training [Internet]. 2021 [cited 2023 Mar 21]. Available from: https://training.cochrane.org/online-learning/core-software/revman/revman-5-download
15. Bartoníček J, Vávra J, Bartoška R, Havránek P. Operative treatment of avascular necrosis of the femoral head after proximal femur fractures in adolescents. Int Orthop. 2012;36(1):149–57.
16. Kim YH, Park JW, Kim JS. Cementless metaphyseal fitting anatomic total hip arthroplasty with a ceramic-on-ceramic bearing in patients thirty years of age or younger. J Bone Jt Surg. 2012;94(17):1570–5.
17. Restrepo C, Lettich T, Roberts N, Parvizi J, Hozack WJ. Uncemented total hip arthroplasty in patients less than twenty-years. Acta Orthop Belg. 2008 Oct;74(5):615–22.
18. Byun JW, Yoon TR, Park KS, Seon JK. Third-Generation Ceramic-On-Ceramic Total Hip Arthroplasty in Patients Younger Than 30 Years with Osteonecrosis of Femoral Head. J Arthroplasty [Internet]. 2012;27(7):1337–43. Available from: http://dx.doi.org/10.1016/j.arth.2011.07.004
19. Clohisy JC, Oryhon JM, Seyler TM, Wells CW, Liu SS, Callaghan JJ, et al. Function and fixation of total hip arthroplasty in patients 25 years of age or younger. Clin Orthop Relat Res. 2010;468(12):3207–13.
20. Costa CR, Johnson AJ, Mont MA. Use of Cementless, Tapered Femoral Stems in Patients Who Have a Mean Age of 20 Years. J Arthroplasty [Internet]. 2012;27(4):497–502. Available from: http://dx.doi.org/10.1016/j.arth.2011.07.005
21. Dudkiewicz I, Salai M, Israeli A, Amit Y, Chechick A. Total hip arthroplasty in patients younger than 30 years of age. Isr Med Assoc J. 2003;5(10):709–12.
22. Finkbone PR, Severson EP, Cabanela ME, Trousdale RT. Ceramic-on-ceramic total hip arthroplasty in patients younger than 20 years. J Arthroplasty [Internet]. 2012;27(2):213–9. Available from: http://dx.doi.org/10.1016/j.arth.2011.05.022
23. Kamath AF, Sheth NP, Hosalkar HH, Babatunde OM, Lee GC, Nelson CL. Modern Total Hip Arthroplasty in Patients Younger Than 21 Years. J Arthroplasty [Internet]. 2012;27(3):402–8. Available from: http://dx.doi.org/10.1016/j.arth.2011.04.042
24. Fujita K, Makimoto K, Tanaka R, Mawatari M, Hotokebuchi T. Prospective study of physical activity and quality of life in Japanese women undergoing total hip arthroplasty. J Orthop Sci [Internet]. 2013 Jan [cited 2022 Dec 29];18(1):45–53. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23096948
25. Kim YH, Kim JS, Cho SH. Primary total hip arthroplasty with the AML total hip prosthesis. Clin Orthop Relat Res. 1999;360:147–58.
26. Mardani-Kivi M, Karimi-Mobarakeh M, Asadi K, Hashemi-Motlagh K, Saheb-Ekhtiari K. Evaluation of clinical outcomes of cementless total hip arthroplasty in patients under 30 years of age. Eur J Orthop Surg Traumatol. 2013;23(7):785–90.
27. Pakos EE, Paschos NK, Xenakis TA. Long term outcomes of total hip arthroplasty in young patients under 30. Arch Bone Jt Surg. 2014;2(3):157–62.
28. Wade R, Shah KA. Functional and radiological outcome of uncemented total hip arthroplasty in young adults - 5 year follow-upollow-up. J Orthop [Internet]. 2020;18(November 2019):237–9. Available from: https://doi.org/10.1016/j.jor.2019.10.014
29. Yoon HJ, Yoo JJ, Yoon KS, Koo KH, Kim HJ. Alumina-on-alumina THA performed in patients younger than 30 years: A 10-year minimum followup study. Clin Orthop Relat Res. 2012;470(12):3530–6.
30. Shan L, Shan B, Graham D, Saxena A. Total hip replacement: a systematic review and meta-analysis on mid-term quality of life. Osteoarthr Cartil [Internet]. 2014 Mar [cited 2022 Dec 29];22(3):389–406. Available from: https://pubmed.ncbi.nlm.nih.gov/24389057/
31. Wang Z, Hou J zhao, Wu C hua, Zhou Y jiang, Gu X ming, Wang H hong, et al. A systematic review and meta-analysis of direct anterior approach versus posterior approach in total hip arthroplasty. J Orthop Surg Res. 2018;13(1):1–11.
32. Zaballa E, Harris EC, Cooper C, Linaker CH, Walker-Bone K. Risk of revision arthroplasty surgery after exposure to physically demanding

occupational or leisure activities: A systematic review. PLoS One [Internet]. 2022 Feb 1 [cited 2022 Dec 29];17(2). Available from: https://pubmed.ncbi.nlm.nih.gov/35226696/

33. Sheehan KJ, Williamson L, Alexander J, Filliter C, Sobolev B, Guy P, et al. Prognostic factors of functional outcome after hip fracture surgery: a systematic review. Age Ageing [Internet]. 2018 Sep 1 [cited 2022 Dec 29];47(5):661–70. Available from: https://academic.oup.com/ageing/article/47/5/661/4969574
34. Sarraf KM, Popat R, Kneale KL, Bhattacharya R, Ramachandran M, Achan P, et al. Functional outcomes, complications and revision rate of hip arthroplasty in patients with sequelae of slipped capital femoral epiphysis: a systematic review. EFORT Open Rev. 2021;6(7):539–44.
35. Okafor L, Chen AF. Patient satisfaction and total hip arthroplasty: a review. Arthroplasty. 2019;1(1):1–7.
36. Adelani MA, Keeney JA, Palisch A, Fowler SA, Clohisy JC. Has total hip arthroplasty in patients 30 years or younger improved? A systematic review hip. Clin Orthop Relat Res. 2013;471(8):2595–601.
37. Gee MJ, Ajuied A, Shah Z, George M, Bankes MJK. Systematic review of total hip arthroplasty in patients under 30 years old. Hip Int [Internet]. 2013 Jul [cited 2023 Mar 22];23(4):345–51. Available from: https://pubmed.ncbi.nlm.nih.gov/23475420/
38. Walker RP, Gee M, Wong F, Shah Z, George M, Bankes MJK, et al. Functional outcomes of total hip arthroplasty in patients aged 30 years or less: A systematic review and meta-analysis. HIP Int. 2016;26(5):424–31.