Arthroplasty Today 23 (2023) 1–5

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

Total Hip Arthroplasty in the Ultrayoung

Matthew Mazur, MD *, Kevin Steelman, MD, Zain Sayeed, MD, MHA, Chaoyang Chen, MD, Hussein Darwiche, MD, Bryan Little, MD

Department of Orthopedic Surgery, Detroit Medical Center, Wayne State University, Detroit, MI, USA

A R T I C L E I N F O

Article history:
Received 4 February 2023
Received in revised form
21 June 2023
Accepted 1 July 2023
Available online xxx

Keywords:
Hip
Arthroplasty
Young
Reconstruction
Total hip arthroplasty

A B S T R A C T

Background: Total hip arthroplasty (THA) procedures provide a surgical option for "ultrayoung" patients ≤30 years old with end-stage hip arthropathy. This has historically been coupled with concerns over early component failure and challenging surgical technique leading to increased risk of overall morbidity. The purpose of this study is to better elucidate the poorly defined indications and outcomes for THA in ultrayoung patients with end-stage hip disease.

Methods: A total of 40 THAs in 35 patients ≤30 years old performed at our institution from 2009 to 2016 were retrospectively followed for an average of 2 years (median 11 months, interquartile range 1-31.25). Primary outcome measure was THA revision. Patient demographics were compared against outcomes. The effects on revision rate of hip joint pathology and type of bearing surface were investigated. T-test, chi-square test, and bivariate correlation were performed to determine statistical significance ($P < .05$). Machine learning was used to determine the normalized important factor leading to THA revision.

Results: Fifteen male and 25 female patients were included. Median patient age was 23 (interquartile range 19-27) years, with an average body mass index of 27.0 ± 7.9. A majority of THAs were indicated for osteonecrosis (32) and bearing surface type was predominantly metal-on-highly cross-linked polyethylene (36). The overall revision rate was 7.5%, without a correlation between revision and demographic characteristics. Revision surgery was significantly correlated with bearing surface type ($P =$ .028). Important factors for revision were age (100%), bearing surface type (84.7%), and body mass index (52.1%).

Conclusions: In patients ≤30 years old, THAs performed with the use of modern implants and surgical methods show satisfactory survivorship and functional outcomes with short-term follow-up.

Introduction

Primary total hip arthroplasty (THA) has proven to be an effective intervention for debilitating hip disease [1–6]. While most of these procedures are performed to address hip osteoarthritis (OA) in the elderly, there is a smaller subset of "ultrayoung" patients ≤30 years of age who may also benefit from THA [7]. These patients primarily suffer from hip arthrosis secondary to deforming conditions such as Legg-Calvé-Perthes [7], slipped capital femoral epiphysis [8], femoral head osteonecrosis [9], and developmental dysplasia of the hip [10]. Regardless of patient age or symptom etiology, the conditions share a common end-stage pathology: articular cartilage destruction resulting in progressive arthrosis and debilitating pain. Surgical intervention is focused on symptom relief and improvement in function.

Surgeons attempting to achieve these goals with THA for patients in the ultrayoung face several unique challenges. One primary concern is for implant longevity and avoidance of revision surgery. Implant failure has been shown to happen more frequently in younger patients who live longer, more active lives than their elderly counterparts [11,12]. Additionally, the presence of bony deformity at the hip can make the planning and technical aspects of surgery significantly more difficult [13]. Although implant design and surgical techniques have evolved to address some of these challenges [14], ultrayoung patients continue to report suboptimal levels of function and satisfaction following THA [15,16]. Hip preservation procedures and hip arthrodesis are reasonable surgical alternatives for these patients, but each comes with a particular

* Corresponding author. 96 Adelaide St., Detroit, MI 48201, USA. Tel.: +1 313 701 3209.

E-mail address: matthew.m.mazur@gmail.com

https://doi.org/10.1016/j.artd.2023.101181
2352-3441/

set of drawbacks and limitations, including residual pain or the need for conversion to THA [7].

While an increasing number of these procedures are being performed for this patient population [17], relative indications and outcomes remain poorly defined [16]. This study outlines the authors' experience with performing THA in the ultrayoung patient population to provide additional short-term results to help guide the surgical decision-making process. We hypothesize that careful and considerate implementation of THA in young patients with end-stage hip disease can provide desirable clinical results despite the challenges involved.

Material and methods

Patient characteristics

This is a retrospective review from a large urban academic center, and approval from our institutional review board was obtained prior to the start of this study. Patients ≤30 years old who underwent primary THA for any reason between September 2009 and January 2016 were included. All THA procedures were performed by one of 2 fellowship-trained arthroplasty surgeons. All patients had previously failed conservative management prior to surgery. Patient demographic data, reason for undergoing THA, presence of complications or revision surgery, and date of final follow-up were obtained from our institution's electronic medical record (EMR). Exclusion criteria included instances of revision arthroplasty and incomplete documentation of operative details and/or postoperative course.

A total of 1250 THA procedures were performed during the study period, and ultimately 40 THA procedures performed on 35 patients were included. This included 15 male hips (37.5%) and 25 female hips (62.5%), with a median patient age of 23 (interquartile range 19-27) years and an average body mass index (BMI) of 27.0 ± 7.9 at the time of index procedure. The age of females at the time of procedure was 24.2 ± 4.5, compared with 20.6 ± 4.9 for males. Patients were followed for an average of 24 months (median 11 months, interquartile range 1-31.25) postoperatively. Indications for THA included osteonecrosis in 32 hips (80%), dysplasia in 5 hips (12.5%), OA in 1 hip (2.5%), inflammatory arthritis in 1 hip (2.5%), and failed prior surgery in 1 hip (2.5%). Two hips (in the same patient) had a history of surgical intervention prior to THA, in the form of periacetabular osteotomy for the first and cerclage wire fixation of a lesser trochanter fracture for the other. Demographic information can be found summarized in Table 1 and Figure 1.

Surgical characteristics

All procedures were performed with the patient in lateral decubitus position, utilizing a posterior approach. One case required an extended trochanteric osteotomy to access and remove hardware from prior surgery. Acetabular and femoral implants were placed with cementless techniques, with supplemental screw fixation for the acetabular component in all cases. Implant-bearing surfaces included metal-on-highly cross-linked polyethylene (MoP), ceramic-on-ceramic (CoC), and metal-on-metal (MoM).

Table 1
Demographic information for patients within the study population.

Total number of hips	40 (Total 35 patients)
Gender	15M; 25F
Age (y)	22.9 (range 12-30)
Female	24.2 ± 4.5
Male	120.6 ± 4.9
Body mass index (BMI)	27.0 ± 7.9
Female	29.3 ± 7.3
Male	23.1 ± 7.6

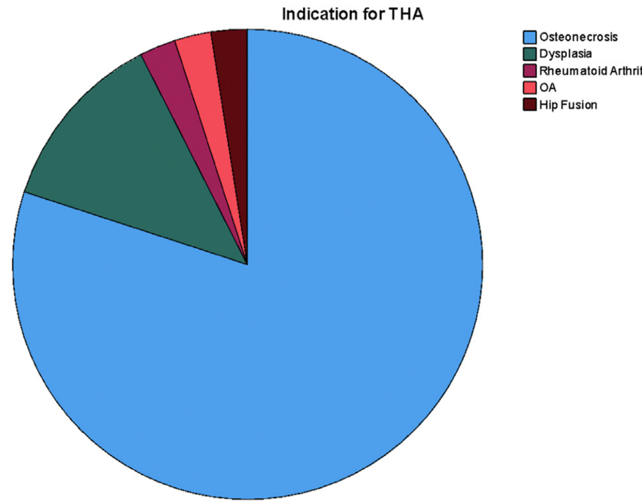

Figure 1. Surgical indications for performing THA within the study population.

Clinical assessment

All patients remained in hospital overnight following surgery, at least until postoperative day 1. Two doses of cefazolin were administered for postoperative antibiotic prophylaxis, and sequential compression devices were used in place of chemical thromboprophylaxis. Clinical data was collected on all patients preoperatively, on the day after surgery, then at 1, 3, and 12 months, and every year thereafter via clinic visits. Hip radiographs were obtained and independently reviewed by both the surgeon and a radiologist at each postoperative visit. Detailed documentation of clinical progression including complications and reoperations was available through the EMR and appropriately noted.

Statistical methods

All analyses were conducted based on individual THA procedures rather than individual patients. Demographic variables including age, gender, and BMI were collected to determine their role in revision. The effects of hip joint pathologies and type of bearing surface on revision rate were investigated. T-test, chi-square test, and bivariate correlation were performed for statistical analysis. Machine learning multilayer perception neural networks were used to determine the normalized important factors leading to THA revision. SPSS software (Version 28, IBM, Armonk, NY) was used for statistical analysis. *P*-value <.05 was considered to be statistically significant.

Results

A total of 40 THA procedures were performed on 35 patients during the study period. The age of females at the time of procedure (24.2 ± 4.5) was significantly higher than males (20.6 ± 4.9) [$P = .026$]. The BMI of females (29.3 ± 7.3) was also significantly higher than in males (23.1 ± 7.6) [$P = .018$]. BMI increased with the increase in age (bivariate correlate, Pearson test, $P = .015$).

Implant bearing surfaces included MoP in 36 cases (90%), CoC in 3 cases (7.5%), and MoM in 1 case (2.5%). All MoP bearings were cobalt-chromium alloy on highly cross-linked. Femoral head sizes ranged from 28 mm to 40 mm.

Radiological outcome

Follow-up radiographs were reviewed for all THAs throughout the duration of the study period. Two cases (5%) showed radiographic evidence of implant loosening. Both were addressed with revision surgery, with their subsequent clinical courses described in the following section.

Complications, reoperations, and revisions

The overall revision rate was 7.5% (3/40 hips) throughout the study period. These included 2 cases of aseptic implant loosening and one case of acute prosthetic joint infection (PJI). The first case of aseptic loosening was related to the acetabular component with a MoP bearing surface (Fig. 2a-e). The acetabular cup was found to be loose 3 years after the index procedure and subsequently revised with a jumbo cup and larger sized femoral head. The second case of aseptic loosening was related to the femoral component with a MoP bearing surface. The loose femoral stem was identified roughly 2 years following the index procedure and revised with a larger sized femoral stem for better medullary fit. Both cases went on to experience an otherwise uncomplicated clinical course after revision. The singular case of PJI was identified 3 weeks after the index procedure with CoC-bearing surface and addressed initially with exchange for a polyethylene liner as well as a course of intravenous antibiotic therapy. Unfortunately, this intervention was unsuccessful in eradicating infection, and a 2-stage revision was pursued along with a prolonged course of antibiotic therapy. The first stage of resection arthroplasty with placement of dynamic antibiotic-coated spacer was performed 2 weeks after liner exchange. The second stage was completed 3 months later with spacer removal and insertion of appropriately sized implants with ceramic-on-polyethylene (CoP) bearing surface. The clinical course following 2-stage revision was otherwise uncomplicated.

Bivariate correlate analysis demonstrated that there was no correlation between revision and sex ($P = .688$), age ($P = .416$), BMI ($P = .298$), or indication ($P = .486$) [Table 2]. Cox hazard analysis demonstrated that cases with osteonecrosis as a surgical indication had a higher rate revision rate than those with OA, but without statistical significance ($P = .628$) [Fig. 3]. The 3 revision cases included 1 hip with CoC bearing surface that experienced PJI, and 2 with MoP bearing surface that experienced aseptic component loosening. Overall, revision surgery was significantly correlated with bearing surface type (Spearman test, $P = .028$). Further analysis with multilayer perception neural networks demonstrated that the normalized importance factors for revision were age (100%), bearing surface type (84.7%), BMI (52.1%), gender (14.8%), and surgical indications (10.1%) [Fig. 4].

Table 2
Bivariate correlate analysis of effects of demographic characteristics on outcome measures.

	Revision		*P*-value
	No	Yes	
Sex			.688
Male	14(93.3%)	1(6.7%)	
Female	23(92.0%)	2(8.6%)	
Age	22.6 ± 4.8	26.3 ± 6.4	.416
BMI	26.7 ± 8.1	30.8 ± 5.1	.298
Indications			.486
Osteonecrosis	30 (93.8%)	2 (6.3%)	
Dysplasia	4 (80.0%)	1 (20.0%)	
Arthritis	3 (100.0%)	0 (0.0%)	
Bearing surface			.277
MoP (metal-on-polyethylene)	34 (94.4%)	2 (5.6%)	
Other	3 (75.0%)	1 (25.0%)	

Discussion

The number of THA procedures performed in the United States continues to increase every year. This is due to reproducibility of surgical technique, low risk of adverse events, and favorable clinical outcomes, [18] which have been well documented for procedures addressing degenerative OA in elderly patients [19]. Despite these overwhelmingly positive results, surgeons remain hesitant to perform a THA on candidates younger than 50 years old [20–23]. This is based on expectations that these patients may outlive their prosthesis due to technological limitations in implant design, in addition to the probability of high cumulative lifetime activity level [24,25]. Early prosthesis failure is an extremely tenuous clinical scenario, typically warranting a subsequent revision arthroplasty while significantly increasing lifetime risk for complications [26]. Concern for high rates of complication and revision has ultimately dictated the limited use of THA in ultrayoung populations, resulting in a lack of good data regarding clinical outcomes using modern surgical techniques. The results of this study suggest that these concern levels may be unnecessarily high, given that THA may be safely and reliably used in the ultrayoung population based on short-term data.

While 10-year revision rates for primary THA in patients >50 years old are below 5%, rates of 5%-20% have been reported for patients younger than 30 years old [27,28]. The revision rate of 7.5% (3/40) reported in this study is consistent with the lower end of the range reported in current literature for ultrayoung patients. These

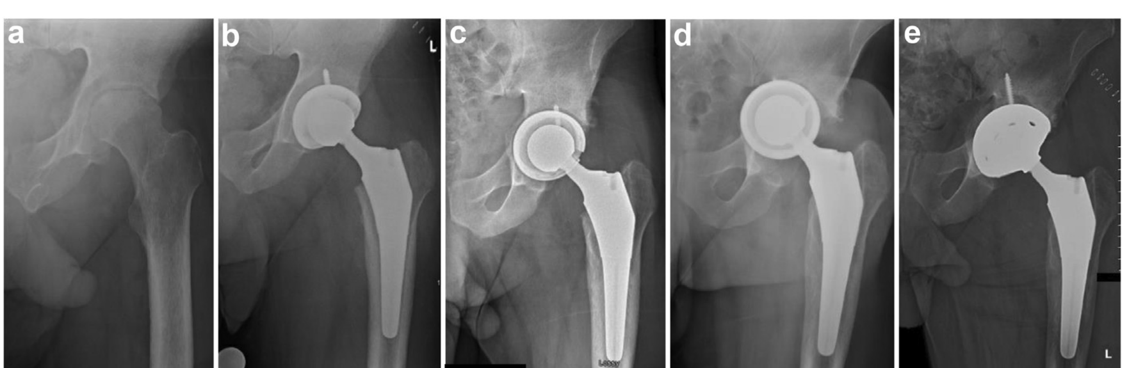

Figure 2. (a) Left hip anterior-posterior radiographs showing preoperative native hip radiographs, (b) immediate postoperative radiographs following primary THA, (c and d) progressive loosening of acetabular component, (e) with subsequent acetabular component revision.

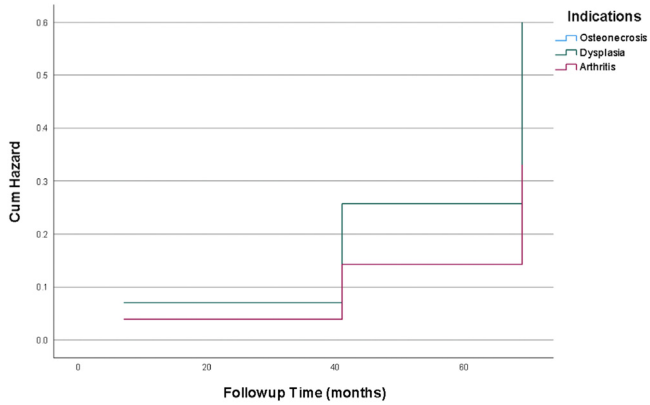

Figure 3. Cox hazard analysis of eventual revision based on surgical indication at index procedure.

revisions were due to component loosening (2) and PJI (1), all of which went on to complete successful clinical courses. Risk for revision was not found to be correlated with the patient demographic factors of gender, age, or BMI. Bearing surface type was, however, significantly correlated with eventual need for revision ($P = .028$). Interestingly, MoP bearing surface was used almost exclusively (36/40 hips, 90%) by the authors in this study. This is unique from other recent, similar studies that incorporate higher percentages of CoP and MoM bearing surfaces. For example, Makarewich et al. [29] published outcome data within the last 5 years that included 145 patients ≤30 years old undergoing THA. The prevalence of MoP-bearing surface use was primarily based on surgeon experience and comfort. The authors reported a revision rate of 11% for this population, with bearing surfaces consisting of CoP in 42% of cases, MoM in 32%, and MoP in 13%. Pallante et al. [14] recently described a cohort of 78 patients ≤20 years old undergoing THA that experienced an overall revision rate of 2.8% at 10 years, with bearing surfaces consisting of CoC in 58% of cases, MoP in 31%, and CoP in 11%. The bearing surface choice may at least partially explain the low revision rate observed in this study and is worth further investigation through more robust future studies on this topic.

Fortunately, relative indications for use of THA in the ultrayoung population are expanding due to recent advances in prosthetic design and surgical technique [16]. Initial investigations into the use of THA for hip arthrosis in the ultrayoung population showed rates of implant loosening up to 50% and rates of revision surgery nearing 40% [30–38]. A vast majority of the procedures utilized cemented acetabular and femoral components, which was later identified as a major contributing factor to poor long-term outcomes [33]. A trend toward the use of cementless components for this population ensued, which has corresponded with increasingly favorable clinical outcomes being reported in recent literature. Shorter-term studies (follow-up of 5 years or less) using either completely cementless or hybrid implant systems have reported improved revision rates below 10% [28,29,39,40]. THA is now increasingly viewed as a viable surgical option for treatment of hip osteonecrosis, early-onset OA, bony tumors, septic arthritis, and slipped capital femoral epiphysis in the ultrayoung patient [9].

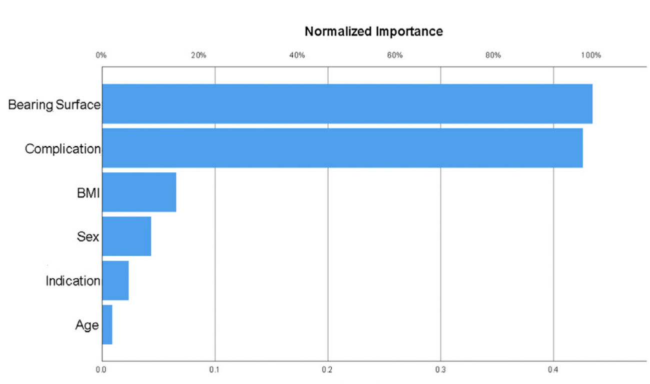

Figure 4. MPNN analysis of normalized importance of factors contributing to revision. MPNN, multilayer perception neural networks.

The methods used to conduct our study reflect recent advances in the application of THA for ultrayoung patients, especially in relation to scope of use and surgical technique. The majority of THA procedures in this study group were performed for cases of osteonecrosis ($n = 27$; 67.5%), often related to sickle cell anemia. Osteonecrosis has similarly been the major indication for THA in recent literature on ultrayoung populations, comprising between 20% and 50% of reported cases [14,28,40–43]. Additionally, cementless acetabular and femoral components were used for all procedures in this study. The majority of bearing surfaces were MoP, with a select number of cases implementing either CoC or MoM surfaces. This provides insight that is unique from comparable recent studies that have utilized a CoC-bearing surface in a majority of patients [14,40,44]. To the authors' knowledge, this represents the first cohort in recent literature that analyzes a population treated exclusively using noncemented implants with a majority of MoP-bearing surfaces. This is representative of an overall trend over the past several years toward cementless implants that utilize MoP-bearing surface in THA for all populations.

Uncertainty on appropriate use and long-term efficacy of alternative surgical interventions for ultrayoung patients, including methods of hip preservation or hip arthrodesis, has led to difficulty in defining a universally accepted treatment algorithm. This, in turn, has placed an increased importance on establishing reliable outcomes following primary THA [15,45,46]. Unfortunately, widespread clinical application of THA in the ultrayoung remains limited by a lack of robust clinical data. The promising results reported suffer from underpowered studies and limited long-term clinical follow-up. Our hope is that the short-term results presented in this study can strengthen the growing body of evidence that supports safe and reliable expansion for use of THA in the ultrayoung population and inspire further investigation.

This study is not without limitations. First, this study was inherently limited by its retrospective nature. Second, our cohort of 40 hips is smaller and thus statistically underpowered when compared with some of the other studies published in the past decade on this topic. The overall follow-up duration is also relatively truncated due to recency of the study period and natural reliance on patient-dictated attendance at postoperative visits. This is, however, a relatively substantial demonstration of outcome data for an uncommon clinical scenario that is not well reported at present. This study was also limited by lack of patient-reported outcome data. Patient contact information was often unreliable and outdated within the EMR, which ultimately made attempts to collect this information and determine meaningful trends difficult, if not impossible. Future studies should include larger cohorts as well as patient-reported outcome data.

Conclusions

In patients ≤30 years old, THAs performed with the use of modern implants and surgical methods show satisfactory survivorship with short-term follow-up, with revision requirements on the lower end of currently reported rates. Eventual need for revision is more closely related to bearing surface than demographic factors. These encouraging results will hopefully inspire multicenter prospective studies with longer follow-up.

Conflicts of interest

The authors declare there are no conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2023.101181.

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