Journal of Clinical Orthopaedics and Trauma 34 (2022) 102042

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

journal homepage: www.elsevier.com/locate/jcot

Total Hip Arthroplasty via direct anterior approach for osteonecrosis; comparison with primary hip osteoarthritis in a mid term follow up

Alireza Moharrami [a, 1], Seyed Peyman Mirghaderi [a, b, 1], Shahin Marzban [a], Seyed Mir Mansour Moazen-Jamshidi [a], Delaram Shakoor [a], Seyed Mohammad Javad Mortazavi [a, *]

[a] Joint Reconstruction Research Center, Tehran University of Medical Sciences, Tehran, Iran
[b] Students' Scientific Research Center (SSRC), Tehran University of Medical Sciences, Tehran, Iran

ARTICLE INFO

Article history:
Received 28 April 2022
Received in revised form
3 September 2022
Accepted 27 September 2022
Available online 3 October 2022

Keywords:
AVN
Femur head necrosis
Total hip arthroplasty
Osteonecrosis
Osteoarthritis

ABSTRACT

Background: To determine the mid-term outcomes of conventional cementless Total Hip Arthroplasty (THA) in patients with avascular necrosis (AVN) of the femoral head and compare to patients with primary hip osteoarthritis (OA).

Method: A total of 330 consecutive primary THA procedures (AVN and OA) performed between 2010 and 2013 by a single surgeon and in a single center using the direct anterior approach (DAA) were included. Assessments including SF-36, WOMAC, and Harris Hip Scores (HHS) were retrieved from patients before the surgery and at the latest follow-up. Clinical and functional outcomes were compared between the AVN and OA groups.

Results: A total of 294 consecutive THA (AVN = 107, OA = 187) with 104.4 ± 6.2 months follow-up were analyzed, which AVN patients were significantly younger (32.0 vs. 59.6 y/o). Corticosteroid 34 (31.8%), idiopathic AVN 31 (29.0%) and use of unapproved weight gain supplements (UWGS) 23 (21.5%) were the main reasons for AVN. Despite that preoperative scores were comparable ($P > 0.05$), the HHS, SF-36, and WOMAC scores are significantly higher in the AVN group after THA surgery ($P < 0.05$). Moreover, flexion and abduction ROM were significantly higher in the AVN group ($P < 0.05$). Regarding each complication, no significant difference was observed between groups. In the whole sample, there were 5 (1.7%) revisions due to loosening of acetabular components, all the OA group ($P > 0.05$).

Conclusion: Conventional cementless THA with highly cross-linked polyethylene provides satisfactory mid-term results in patients with AVN with a low rate of postoperative complications. Compared to primary OA patients, this group reaches superior postoperative scores.

1. Introduction

Orthopedic practitioners continue to face challenges in managing patients with advanced stages of Avascular necrosis (AVN) of the femoral head.[1,2] AVN of the femoral head is a debilitating condition with diverse causes and poorly understood pathophysiology, which often results in secondary hip osteoarthritis (OA).[3,4] When the disease has advanced to the final stages, the femoral head is collapsed, making methods of joint preservation, such as core decompression, varus osteotomy, and percutaneous drilling undesirable. Unfortunately, many patients present when the femoral head collapse is beyond salvage; thus, THA remains the only recommended option.[3,5–11]

Old studies evaluating the outcome of THA in AVN patients showed unacceptable clinical results with a high failure rate.[5,12] Most of these data were extracted from studies with cemented and old designed components. In line with, some recent studies claimed a higher rate of complications (sepsis, SSI, pneumonia, transfusions, and readmissions) and failure after THA among AVN patients than non-AVN patients.[13–16] On the other hand, other

* Corresponding author. Joint Reconstruction Research Center, Tehran University of Medical Sciences, Tehran, Iran.
E-mail addresses: a.moharramy@gmail.com (A. Moharrami), mirghaderi76@gmail.com (S.P. Mirghaderi), shahinmarzban@yahoo.com (S. Marzban), moazen.jamshidi@yahoo.com (S.M.M. Moazen-Jamshidi), delaramshakoor@mail.com (D. Shakoor), smjmort@yahoo.com (S.M.J. Mortazavi).
[1] A Moharrami and SP Mirghaderi contributed equally to this work (Co-first author).

https://doi.org/10.1016/j.jcot.2022.102042
0976-5662/

recent studies have found THAs for AVN patients to be safe and to result in the comparable outcomes as THAs for patients with primary osteoarthritis[17–20]; the advent of the cementless prosthesis with enhanced bearing surface material has improved the outcome of this procedure in individuals with AVN.[1,3,19,21,22] Due to the high level of activity and long lifespan of this group of patients, concerns have been raised regarding the effectiveness and longevity of prostheses. Poor bone quality can also be an issue when AVN is caused by systemic etiologies such as long-term steroid use and alcoholism.[19,23]

The purpose of this study is to determine whether the clinical and radiographic outcomes and survivorship of cementless THA among patients with AVN are acceptable at mid-term follow-up. A comparison was made between the outcome of THA in patients with AVN and that of THA in patients with primary OA to achieve this goal.

2. Methods

2.1. Subjects and design

Between April 2010 and April 2013, 435 primary uncemented THA was performed on 360 patients in Imam Khomeini hospital, Tehran, Iran, as a tertiary center. The inclusion criteria consist of uncemented, primary THA indicated for AVN or primary OA. Patients with other indications were not included. 330 THAs from the prospectively collected database were enrolled in this retrospective cohort study. Among this initial group, 33 patients were excluded because the data were insufficient or they were lost to follow-up hips, and 3 individuals died during the follow-up period. We had 36 numbers of THA loss to complete follow-up and did not consider them in the final analysis, remaining with 294 replaced hips (Fig. 1). An average of 4.8 years passed before patients were lost to follow-up (range 0–7 years). Seven years of follow-up is considered a minimum for inclusion in the final analysis. All aspects of this study were reviewed and approved by the ethics committee and Institutional Review Board (IRB) of our University of Medical Sciences.

2.2. Surgical procedure

All surgeries were performed in one institution by the senior author (SMJ.M) through the direct anterior approach (DAA). A capsular exposure was then followed by an anterior capsulectomy to access the head and neck. Following a double neck osteotomy, the head was removed. An incision was made in the medial capsule to allow placement of retractors and better visualization of the acetabulum. During this procedure, it was necessary to release the soft tissues around the greater trochanter and piriformis fossa to lift the proximal femur through the incision to broach the canal appropriately. The DAA procedure did not involve tenotomy or skeletal or skin traction. In all surgeries, metal on a highly cross-linked polyethylene prosthesis was utilized. For the femoral component, proximally coated, taper Fitmore® stem (Zimmer, Inc.; Warsaw, IN) and HA-coated, taper CORAIL® implant (DePuy Orthopaedics, Inc.) was used. For the acetabular component, porous-coated, hemispherical Trilogy® acetabular cup (Zimmer, Inc.; Warsaw, IN) and porous-coated PINNACLE® acetabular cup (DePuy Orthopaedics, Inc.) was employed.

Pre and postoperative care were similar in all participants according to the same protocol. Before the surgery, patients received 2 gm prophylactic antibiotics (first generation Cephalosporin), 500 mg Acetaminophen, and 200 mg Celecoxib. Following surgery, thromboprophylaxis (ASA 325 mg every 12 h) was performed accordingly to AAOS guidelines.[24] In accordance with the standard of care at our center, patients were mobilized on the day of surgery with the aid of walkers or crutches, using them for approximately four weeks after surgery. Brace was not employed in any patient. Preoperative templating was performed using mediCAD® software for all cases.[25]

2.3. Clinical evaluation and follow up

One-two days before the procedure, patients were examined and asked to complete SF-36 and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) questionnaires. WOMAC index is a self-administered questionnaire provided for outcome measures of hip arthroplasty. It contains three aspects of pain (5 items), stiffness (2 items), and function (17 items), scaled from zero to 100 (worst to best score).[26] SF-36 is a widely used, reliable, self-administered form for evaluating the quality of life with eight dimensions.[27] Two summary scores are generated by the SF-36: the physical component summary (PCS) and mental component summary (MCS).[26] Also, according to the patient's physical findings, the examiner completed Harris Hip Score (HHS), a valid determinant of functional level.[28] They had their range of motion (ROM) measured by a goniometer by an experienced examiner. Following surgery, all patients were visited regularly in the clinic during the first postoperative week, at 1, 3, 6 and 12 months and then annually thereafter. These visits were conducted by expert orthopedic residents, during which complications were evaluated and HHS and ROM were recorded. An anterior-posterior (AP) and lateral radiographic series were taken to assess the position of implants and possible loosening or osteolysis. Migration of the cup, broken screws or complete radiolucent lines at the interface are all indications of loosening. Having a radiolucent line >1 mm in 2 or more DeLee zones was considered radiolucency.[29] At the final follow-up, patients completed SF-36 and WOMAC questionnaires. The mean time of follow-up was 104.4 ± 6.2 months (range: 7–11 years, Average follow-up in AVN group: 105.4 ± 8.6 months, OA group: 103.9 ± 7.8 months, $P = 0.2$). Three patients in the OA group passed away for other reasons at the time of follow-up and were excluded from the study. Patients who had incomplete data or follow-up loss were excluded (Fig. 1).

2.4. Statistical analysis

SPSS software (version 25, IBM SPSS, INC) was employed to perform statistical analysis. The qualitative data between the two groups were compared with the chi-square test ($\chi 2$) or Fisher-exact test. A paired T-test was used to compare Pre and postoperative quantitative data in each group. Kruskal-Wallis ANOVA by ranks and median test with multiple comparisons between two groups were utilized to analyze all the variables. All data are shown in the form of mean ± SD form, and P-value < 0.05 was considered significant.

3. Results

A total of 294 consecutive THA was analyzed, 107 THAs were performed on 81 patients with AVN, and the rest was performed on 162 patients with primary OA of the hip. In the AVN group, mean age was 32.0 ± 6.0 years old, 17 (15.9%) THAs were performed on male patients, and in the OA group, mean age was 59.6 ± 2.2 years old ($P < 0.001$), 122 (65.2%) THAs were performed on female subjects (Table 1). Regarding etiologies of AVN, following corticosteroid 34 (31.8%) and idiopathic AVN 31 (29.0%), the use of unapproved weight gain supplements (UWGS) 23 (21.5%) and trauma 15 (14.0%) were the main reasons in subjects (Table 1).

Except for one case of femoral nerve palsy that healed spontaneously, there was no acute complication throughout all THA

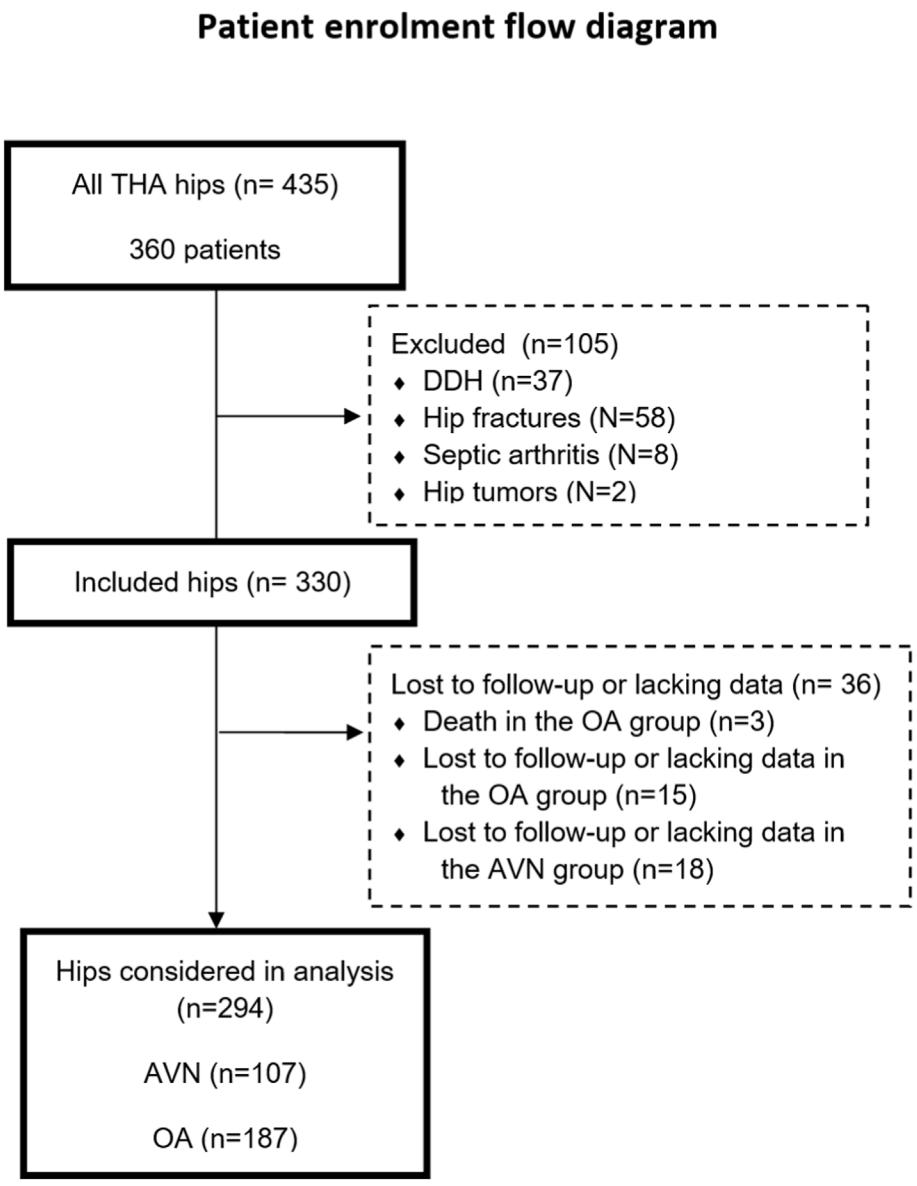

Fig. 1. Patient enrolment flow diagram.

Table 1
Demographics and types of Prosthesis.

		AVN group (N = 107 hips)	OA group (N = 187 hips)	*P*-value
Age (Mean ± SD)		32.0 ± 6.0	59.6 ± 2.2	<0.001
BMI (kg/m^2)		26.1 ± 2.7	26.5 ± 2.8	0.23
Follow-up (Mean ± SD)		105.4 ± 8.6 months	103.9 ± 7.8 months	0.20
AVN etiology	Corticosteroid	34 (31.8%)		
	Idiopathic	31 (29.0%)		
	UWGS	23 (21.5%)		
	Trauma	15 (14.0%)		
	Hemophilia	3 (2.8%)		
	SLE	1 (0.9%)		
Gender	Male	17 (15.9%)	122 (65.2%)	<0.001
	Female	90 (84.1%)	65 (34.8%)	
Implant				
Femoral Component	Zimmer Fitmore®	55 (51.4%)	146 (78.1%)	<0.001
	DePuy CORAIL®	52 (48.6%)	41 (21.9%)	
Acetabular Component	Zimmer Trilogy®	55 (51.4%)	146 (78.1%)	<0.001
	DePuy PINNACLE®	52 (48.6%)	41 (21.9%)	

Abbreviations: **AVN**; avascular necrosis, **OA**; osteoarthritis, **HHS**; Harris Hip Scores, **UWGS;** unapproved weight gain supplements, **SLE;** systemic lupus erythematous.

procedures, including excessive bleeding, trochanteric fracture, etc. Regarding early complications, one surgical site infection occurred in the OA group; other early complications (hematoma, deep vein thrombosis, and symptomatic thromboembolism) were not detected.

HHS, SF-36, and WOMAC scores significantly improved at the final follow-up in both groups compared with preoperative scores ($P < 0.001$). Comparing two groups, preoperative scores' means were not significantly different ($P > 0.05$). Despite that, the HHS, SF-36 (both MCS and PCS domains), and WOMAC scores are significantly higher in the AVN group after THA surgery ($P < 0.05$) (Table 2). In addition, Means of preoperative ROM were not significantly different between groups ($P > 0.05$). However, flexion and abduction ROM were significantly higher in the AVN group ($P < 0.05$) (Table 3).

Regarding complications, no significant difference was observed between groups at the end of the follow-up **(Table 4)**. In the whole sample, there were 5 (1.7%) revisions due to loosening of acetabular components, 9 (3.1%) dislocations that required close reduction, 3 (1.0%) patients with infections that were treated with irrigation and antibiotic therapy, one case of femoral nerve palsy, and one case of Brooker class II heterotopic ossification. A total of nine dislocations occurred, four within the first months after surgery, four within a year, and one within two years. Six of these patients had anterior dislocations and three had posterior dislocations. Four cases were due to the same level falling; three were due to extensive hyperflexion (squatting), and two were cup malpositioning (including the AVN patient). There were no fractures in the entire population.

All acetabular and femoral components in our AVN group showed firm osseous ingrowth in the latest radiograph; However, five patients in the OA group required revision THA due to cup loosening. There was osteolysis associated with loosening in two of them.

4. Discussion

A prominent feature of AVN is its tendency to affect people younger than 50 with high activity levels and a long life expectancy. Therefore, knowing the outcomes and complications of THA and prosthesis longevity in these patients is crucial, and longer follow-ups may be necessary to conclude.[30] The present study compared the clinical and radiographical outcomes of THA through DAA in patients with AVN versus individuals with primary hip OA. Moreover, we determined the efficiency of THA using conventional cementless implants with highly cross-linked polyethylene bearings in managing patients with AVN. This study suggests that THA through DAA for AVN patients with the above prosthesis and performed by an experienced surgeon has mid-to-long-term favorable results with low rates of complications and revisions. Additionally, patients with AVN achieved superior postoperative results regarding HHS, WOMAC, SF-36, and ROM compared to the OA group. Since the calculated minimal clinically important difference (MCID) for WOMAC, SF-36 PCS, and SF-36 MCS were 10.8, 6.7, and 6.2 After THA,[31] the between-group differences did not meet the MCID. All in all, conclusions about implant longevity may require longer follow-ups.

Osawa et al. conducted a matched case-control study of 86 hips with AVN and 86 hips with OA who were matched for age and sex with a 10-year follow-up period. There was no significant difference in HHS and pain outcomes, complications and survival, or PCS of SF-36 between patients with AVN and those with OA.[20] However, they revealed low mental scores among AVN patients (MCS of SF-36), and inferior satisfaction, but higher ROM at the final follow-up. The implant survival rate and rate of complications for cementless THAs were comparable between AVN (97.5%) and OA (98.2%) patients.[20] Similarly, we found similar complications and survival rates between the groups, and superior ROM in the AVN group. Meanwhile, Radl et al. identified significantly more stem migration in AVN than OA patients, with lower survivorship (74% versus 98%).[15] As a result, they recommended close monitoring of them. In summary, In recent years, innovations in implant design have caused cementless THA for AVN treatment to have a ten-year survival rate of 89–99%.[30,32]

Concerning patient-reported outcome measures (PORM), scant studies compared the AVN and OA patients. According to Osawa et al., no significant differences were found between patients with AVN and OA in terms of HHS and pain outcomes, complications and survival, and PCS of SF-36 [20]. In contrast, we observed superior HHS and other PROMs among the AVN patients. The reason for this may be that their study subjects were matched for age and sex, while our study has a significantly older OA group. Even after THA, older patients are more limited and are unable to achieve maximum scores. According to Joly et al.,[33] younger patients had greater improvements in the WOMAC at 3 months and patients over 55 had higher WOMAC scores at 12 months after surgery.

As already known, the outcome of THA procedures is affected by several factors, such as the type of prosthesis, whether cemented or not, surgical techniques, and patient characteristics, including preoperative diagnosis and functional level.[34–36] According to a large body of evidence, cemented THA was associated with

Table 2
Comparison of functional Pre and post-operative scores between the groups.

Pre-operative Scores (mean ± SD)			
	AVN group	OA group	*P*-value
HHS	27.5 ± 13.7	24.5 ± 10.3	0.08
SF-36 (PCS)	22.0 ± 4.6	22.1 ± 4.6	0.8
SF-36 (MCS)	29.2 ± 6.3	28.7 ± 5.4	0.5
WOMAC	10.8 ± 8.0	11.1 ± 8.4	0.7
Post-operative Scores (Difference from the baseline, mean ± SD)			
HHS	94.7 ± 7.1 (67.2 ± 10.1)	92.2 ± 9.3 (67.7 ± 10.2)	0.04
SF-36 (PCS)	54.7 ± 3.8 (32.7 ± 4.3)	49.4 ± 3.6 (27.2 ± 4.2)	0.001
SF-36 (MCS)	53.1 ± 4.1 (23.9 ± 5.7)	50.6 ± 5.0 (21.9 ± 5.4)	0.001
WOMAC	93.4 ± 13.7 (82.6 ± 9.1)	91.0 ± 10.3 (79.9 ± 8.9)	0.01

Abbreviations: **AVN**; avascular necrosis, **OA**; osteoarthritis, **HHS**; Harris Hip Scores, **PCS**; physical component summary, **MCA**; mental component summary, **WOMAC**; Western Ontario and McMaster Universities Osteoarthritis Index.

Table 3
Comparison of range of motion between the two groups.

Preoperative Score (mean ± SD)			
Range of Motion (degree)	AVN group	OA group	*P*-value
Flexion	75.2 ± 7.7	76.2 ± 8.7	0.4
Internal rotation	15.2 ± 5.7	18.2 ± 6.2	0.5
External rotation	22.2 ± 5.6	23.4 ± 5.7	0.5
Abduction	17.2 ± 4.6	17.2 ± 4.3	0.4
Postoperative Score (Difference from the baseline, mean ± SD)			
Flexion	119.9 ± 17.7 (44.7 ± 10.1)	108.3 ± 15.4 (32.1 ± 9.5)	0.01
Internal rotation	40.3 ± 8.0 (25.1 ± 6.8)	40.1 ± 10 (67.2 ± 10.1)	0.4
External rotation	47.5 ± 4.5 (25.3 ± 4.1)	44.3 ± 5.3 (20.8 ± 5.0)	0.5
Abduction	50.9 ± 9.6 (33.7 ± 5.1)	47.0 ± 10.4 (29.8 ± 6.1)	0.04

Abbreviations: **AVN**; avascular necrosis, **OA**; osteoarthritis.

Table 4
Comparison of Post-operative Complications between the groups*.

	AVN group	OA group	*P*-value*
Dislocation	1 (0.9%)	8 (4.3%)	0.2
Periprosthetic joint infection	0	3 (1.6%)	0.5
Revision	0	5 (2.7%)	0.2
Heterotopic Ossification	0	1 (0.5%)	1
Femoral Nerve Palsy	0	1 (0.5%)	1

Abbreviations: **AVN**; avascular necrosis, **OA**; osteoarthritis.
* analyzed with Fisher-exact test.

disappointing results in treating AVN patients.[5,12,30,37–40] Since the failure and loosening of prostheses are quite common, a biological solution for fixing implants using porous coatings has been developed.[5] Recent studies indicated that uncemented components have a long-lasting fixation with a low rate of complication and loosening even in the young population such as AVN patients.[6,21,30,41–43] However, due to a more active lifestyle and higher demand for prosthesis, concerns regarding classic polyethylene high wear rate and consequent osteolysis have raised in the last decade.[43] The arrival of highly cross-linked polyethylene has reduced the wear rate and subsequent osteolysis due to fewer particles generated by the polyethylene liner that initiates wear and implant loosening.[19]

In the AVN group, no radiographic evidence of acetabular and femoral stem loosening or osteolysis was observed, and no revision was performed due to component loosening. Our findings are consistent with recent studies evaluating the outcome of contemporary cementless THA using highly cross-linked polyethylene liner in patients with AVN. In one report on 162 hips with AVN, no revision was performed due to mechanical loosening after a minimum five-year follow-up, and they attributed this success to a low wear rate.[6,19,44] Unfortunately, we could not assess wear rate; however, Wan et al. suggested that the development of osteolysis is directly related to poor bone fixation[45] and all acetabular and femoral components in our AVN group showed firm osseous ingrowth in the latest radiograph. Moreover, five revisions in the OA group due to acetabular component loosening were performed in older patients with osteoporosis and poor bone fixation.

We assume that the surgical technique partly explains the low rate of complications and acceptable outcomes among the AVN patients who underwent THA. All surgeries were performed through the DAA. Unlike the posterior approach, this technique does not entail muscle detachment from the pelvis or femur.[46] This is of utmost clinical importance since posterior structures, and external rotators are preserved, increasing joint stability, thus reducing the risk of posterior dislocation.[47] Furthermore, the lateral approach is accomplished with a detachment of gluteus medius and minimus from the greater trochanter, which results in postoperative limping, and these muscles are left intact in the DAA.[48] Another advantage of this approach is the preservation of gluteus maximus and tensor fascia lata muscles, which are pelvic stabilizers. These major hip abductors are considered as the deltoid of hip that help to reduce the risk of postoperative limping. Hence, less abductor dysfunction and faster rehabilitation are obtained in the anterior approach.[47] The pooled estimates of the length of stay and dislocation revealed a significant advantage for the anterior approach in the Higgins et al. study.[49] However, a long-term perspective does not show any superiority in terms of approaches.[49]

Although the DAA has many advantages, including the ideal component orientation, an overall dislocation rate of 0.6% has been mentioned for this procedure.[47] It is noteworthy that surgeon's experience influences outcomes of DAA and complications are significantly more common when they are on their learning curve.[50] The learning curve varies with each surgical technique, so an experienced surgeon should be sought for training when learning the technique.[50] In our study, a higher dislocation rate (3.1%) was observed. However, all dislocations except one occurred in the OA group. The patients in this group are significantly older and have other disabilities and comorbidities. The presence of low back pain, decreasing visual acuity, and OA at other joints may result in more falls and dislocations in the elderly. In addition, due to the long-term course of osteoarthritis, these patients do not have strong muscle back up to support their implants. Moreover, elderly patients are more difficult to educate, and fewer precautions are taken for their safety, such as preventing hyperflexion. As a result, more falls and inappropriate posture among them is expected.

As a side result, we determined the femoral head AVN etiologies in our study. Dudkiewicz et al. study claimed that despite no effects of the etiology, the steroid-induced AVN patients had a less favorable long-term implant survival rate.[21] The administration of corticosteroid and idiopathic AVN were the most common cause of AVN in the present study. Following these reasons, the use of unapproved weight gain supplements (UWGS) was our institute's third cause of AVN. In a pharmacological study by Saberi et al. in our country, they determined the herbal weight gain supplements sold in herb shops. Their investigation revealed that the supplements contained cyproheptadine (0.2–67 mg/tablet), tramadol, dexamethasone (5.5–10.1 mg/tablet), sildenafil and acetaminophen.[51] In a cautionary report by Mortazavi et al., they found that UWGS

was the third cause of femoral head AVN (~21%) with idiopathic mechanisms.[52]

The present study has some limitations. First, this is a retrospective study, and we could not match patients between AVN and OA group, with approximately 10% lost to follow-up, and the mean age in the former group was significantly lower. Second, we could not measure wear rate; however, all patients were visited, and the patient's radiographs were assessed for bony ingrowth and presence of wear and mechanical osteolysis. Third, our AVN group constituted non-homologous patients with different etiologies. We could not compare THA outcomes between different etiological groups due to the small sample size. Fourth, we used two types of components in each group, though the surgical technique, team, and pre and postoperative protocol were similar. Fifth, the examiner was not the same during this mid-term follow-up study and may result in observer bias. However, all examiners are senior orthopedic residents who were members of the surgery team. Last but not least, the results might not be applicable to all surgeons, especially those who are on their learning curve or are adopting the DAA in their practice.

5. Conclusion

In conclusion, the present study's findings suggest that conventional cementless THA with highly cross-linked polyethylene is accompanied by acceptable and satisfactory results in both AVN and OA groups in mid-term follow-up. The results are also superior in patients with AVN regarding postoperative scores and complication rate. Patients with AVN who are active and expected to live a long time can benefit from conventional cementless THA through DAA with highly cross-linked polyethylene, which is associated with few complications and good results. Further longitudinal studies with a vast sample size clarify more evidence regarding uncemented THA among AVN patients.

Funding

There is no funding source for authors to declare.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent to participate

An informed consent signed by all the study participants.

Consent to publish

Patient consent was obtained regarding the publication of data and photographs.

Author contributions

"A. Moharrami designed the study and edit the manuscript. SP. Mirghaderi wrote the initial draft and edited the final manuscript. Sh. Marzban SMJ. Mortazavi introduced the concept, supervised and designed the study, and edited the final manuscript. D. Shakoor and SMM. Moazen-Jamshidi collected and analyzed data and edited the final manuscript. All authors read and approved the final manuscript"

Availability of data and material

Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

None.

References

1. Hartley WT, McAuley JP, Culpepper WJ, Engh Jr CA, Engh CA. Osteonecrosis of the femoral head treated with cementless total hip arthroplasty. *JBJS*. 2000;82:1408.
2. Migliorini F, Maffulli N, Baroncini A, Eschweiler J, Tingart M, Betsch M. Prognostic factors in the management of osteonecrosis of the femoral head: a systematic review. *Surgeon*. 2022.
3. Issa K, Pivec R, Kapadia B, Banerjee S, Mont M. Osteonecrosis of the femoral head: the total hip replacement solution. *Bone Joint J*. 2013;95:46–50.
4. Lieberman J, Berry DJ, Mont M, et al. Osteonecrosis of the hip: management in the 21st century. *Instr Course Lect*. 2003;52:337–355.
5. Brinker MR, Rosenberg AG, Kull L, Galante JO. Primary total hip arthroplasty using noncemented porous-coated femoral components in patients with osteonecrosis of the femoral head. *J Arthroplasty*. 1994;9:457–468.
6. Johannson HR, Zywiel MG, Marker DR, Jones LC, McGrath MS, Mont MA. Osteonecrosis is not a predictor of poor outcomes in primary total hip arthroplasty: a systematic literature review. *Int Orthop*. 2011;35:465–473.
7. Sheikhbahaei E, Mirghaderi SP, Moharrami A, Habibi D, Motififard M, Mortazavi SMJ. Incidence of symptomatic COVID-19 in unvaccinated patients within one month after elective total joint arthroplasty: a multicenter study. *Arthroplasty Today*. 2022;14:110–115.
8. Mirghaderi SP, Baghdadi S, Salimi M, Shafiei SH. Scientometric analysis of the top 50 most-cited joint arthroplasty papers: traditional vs altmetric measures. *Arthroplasty Today*. 2022;15:81–92.
9. Mirghaderi SP, Sheikhbahaei E, Salimi M, et al. COVID-19 infection rate after urgent versus elective total hip replacement among unvaccinated individuals: a multicenter prospective cohort amid the COVID-19 pandemic. *Ann Med Surgery*. 2022;80, 104307.
10. Moharrami A, Mirghaderi SP, Hoseini-Zare N, et al. Restoring femoral medial offset could reduce pelvic obliquity following primary total hip arthroplasty, an observational study. *Int Orthop*. 2022.
11. Salimi A, Mirghaderi SP, Gholamzadeh MJ, et al. Evaluation of crossover sign in pelvis models made with a three-dimensional printer. *Adv Orthopedics*. 2022;2022, 4665342.
12. Ortiguera CJ, Pulliam IT, Cabanela ME. Total hip arthroplasty for osteonecrosis: matched-pair analysis of 188 hips with long-term follow-up. *J Arthroplasty*. 1999;14:21–28.
13. Sodhi N, Anis HK, Coste M, Piuzzi NS, Jones LC, Mont MA. Thirty-day complications in osteonecrosis patients following total hip arthroplasty. *J Arthroplasty*. 2020;35:2136–2143.
14. Stavrakis AI, SooHoo NF, Lieberman JR. A comparison of the incidence of complications following total hip arthroplasty in patients with or without osteonecrosis. *J Arthroplasty*. 2015;30:114–117.
15. Radl R, Hungerford M, Materna W, Rehak P, Windhager R. Higher failure rate and stem migration of an uncemented femoral component in patients with femoral head osteonecrosis than in patients with osteoarthrosis. *Acta Orthop*. 2005;76:49–55.
16. Mirghaderi SP, Hoveidaei AH, Sheikhbahaei E, Motififard M, Moradi N, Moradi M. Femoral stem dislocation caused by trunnionosis along with adverse local tissue reaction; A case report and a new technique of head to cone cementing. *Arch Bone Jt Surg*. 2022.
17. Kim SC, Lim YW, Jo WL, Park SB, Kim YS, Kwon SY. Long-term results of total hip arthroplasty in young patients with osteonecrosis after allogeneic bone marrow transplantation for hematological disease: a multicenter, propensity-matched cohort study with a mean 11-year follow-up. *J Arthroplasty*. 2021;36:1049–1054.
18. Hart A, Janz V, Trousdale RT, Sierra RJ, Berry DJ, Abdel MP. Long-term survivorship of total hip arthroplasty with highly cross-linked polyethylene for osteonecrosis. *J Bone Joint Surg Am*. 2019;101:1563–1568.
19. Min B-W, Lee K-J, Song K-S, Bae K-C, Cho C-H. Highly cross-linked polyethylene in total hip arthroplasty for osteonecrosis of the femoral head: a minimum 5-year follow-up study. *J Arthroplasty*. 2013;28:526–530.
20. Osawa Y, Seki T, Takegami Y, Kusano T, Makida K, Ishiguro N. Cementless total hip arthroplasty for osteonecrosis and osteoarthritis produce similar results at ten years follow-up when matched for age and gender. *Int Orthop*. 2018;42:

1683–1688.
21. Dudkiewicz I, Covo A, Salai M, Israeli A, Amit Y, Chechik A. Total hip arthroplasty after avascular necrosis of the femoral head: does etiology affect the results? *Arch Orthop Trauma Surg*. 2004;124:82–85.
22. Kakaria H, Sharma A, Sebastian B. Total hip replacement in avascular necrosis of femoral head. *Med J Armed Forces India*. 2005;61:33–35.
23. Radl R, Egner S, Hungerford M, Rehak P, Windhager R. Survival of cementless femoral components after osteonecrosis of the femoral head with different etiologies. *J Arthroplasty*. 2005;20:509–515.
24. Eubanks JD. Antifibrinolytics in major orthopaedic surgery. *JAAOS-J Am Acad Orthopaedic Surgeons*. 2010;18:132–138.
25. Mirghaderi SP, Sharifpour S, Moharrami A, et al. Determining the accuracy of preoperative total hip replacement 2D templating using the mediCAD® software. *J Orthop Surg Res*. 2022;17:222.
26. Nadrian H, Moghimi N, Nadrian E, et al. Validity and reliability of the Persian versions of WOMAC osteoarthritis index and lequesne algofunctional index. *Clin Rheumatol*. 2012;31:1097–1102.
27. Montazeri A, Goshtasebi A, Vahdaninia M, Gandek B. The Short Form Health Survey (SF-36): translation and validation study of the Iranian version. *Qual Life Res*. 2005;14:875–882.
28. Söderman P, Malchau H. Is the Harris hip score system useful to study the outcome of total hip replacement? *Clin Orthop Relat Res*. 2001;384:189–197.
29. Bingham JS, Hinckley NB, Deckey DG, Hines J, Spangehl MJ. Primary Tritanium acetabular components have increased rates of radiolucency associated with inferior clinical outcomes at short-term follow-up. *Hip Int*. 2021, 1120700020988723.
30. Kim Y-H, Choi Y, Kim J-S. Cementless total hip arthroplasty with ceramic-on-ceramic bearing in patients younger than 45 years with femoral-head osteonecrosis. *Int Orthop*. 2010;34:1123–1127.
31. Yeo MGH, Goh GS, Chen JY, Lo NN, Yeo SJ, Liow MHL. Are oxford hip score and western Ontario and McMaster Universities osteoarthritis index useful predictors of clinical meaningful improvement and satisfaction after total hip arthroplasty? *J Arthroplasty*. 2020;35:2458–2464.
32. Han SI, Lee JH, Kim JW, Oh CW, Kim SY. Long-term durability of the CLS femoral prosthesis in patients with osteonecrosis of the femoral head. *J Arthroplasty*. 2013;28:828–831.
33. Ancelin D, Reina N, Cavaignac E, Delclaux S, Chiron P. Total hip arthroplasty survival in femoral head avascular necrosis versus primary hip osteoarthritis: case-control study with a mean 10-year follow-up after anatomical cementless metal-on-metal 28-mm replacement. *Orthop Traumatol Surg Res*. 2016;102:1029–1034.
34. Holtzman J, Saleh K, Kane R. Effect of baseline functional status and pain on outcomes of total hip arthroplasty. *JBJS*. 2002;84:1942–1948.
35. Jones CA, Beaupre LA, Johnston D, Suarez-Almazor ME. Total joint arthroplasties: current concepts of patient outcomes after surgery. *Rheum Dis Clin N Am*. 2007;33:71–86.
36. Röder C, Parvizi J, Eggli S, Berry DJ, Müller ME, Busato A. The Frank Stinchfield Award: demographic factors affecting long-term outcome of total hip arthroplasty. *Clin Orthop Relat Res*. 2003;417:62–73.
37. Cornell C, Salvati E, Pellicci P. *Long-term Follow-Up of Total Hip Replacement in Patients with Osteonecrosis*. vol. 16. The Orthopedic clinics of North America; 1985:757–769.
38. Saito S, Saito M, Nishina T, Ohzono K, Ono K. Long-term results of total hip arthroplasty for osteonecrosis of the femoral head. A comparison with osteoarthritis. *Clin Orthop Relat Res*. 1989:198–207.
39. Salvati EA, Cornell CN. Long-term follow-up of total hip replacement in patients with avascular necrosis. *Instr Course Lect*. 1988;37:67–73.
40. Sarmiento A, Ebramzadeh E, Gogan W, McKellop H. Total hip arthroplasty with cement. A long-term radiographic analysis in patients who are older than fifty and younger than fifty years. *J Bone Joint Surg*. 1990;72:1470–1476. American volume.
41. Babis GC, Soucacos PN. *Effectiveness of Total Hip Arthroplasty in the Management of Hip Osteonecrosis*. vol. 35. The Orthopedic Clinics of North America; 2004:359–364.
42. Baek S-H, Kim S-Y. Cementless total hip arthroplasty with alumina bearings in patients younger than fifty with femoral head osteonecrosis. *JBJS*. 2008;90:1314–1320.
43. Kim Y-H, Oh S-H, Kim J-S, Koo K-H. Contemporary total hip arthroplasty with and without cement in patients with osteonecrosis of the femoral head. *JBJS*. 2003;85:675–681.
44. Dorr LD, Wan Z, Shahrdar C, Sirianni L, Boutary M, Yun A. Clinical performance of a Durasul highly cross-linked polyethylene acetabular liner for total hip arthroplasty at five years. *JBJS*. 2005;87:1816–1821.
45. Wan Z, Dorr LD. Natural history of femoral focal osteolysis with proximal ingrowth smooth stem implant. *J Arthroplasty*. 1996;11:718–725.
46. DeVVal H, Su E, DiCesare PE. *Instability Following Total Hip Arthroplasty*. 2003.
47. Matta JM, Shahrdar C, Ferguson T. Single-incision anterior approach for total hip arthroplasty on an orthopaedic table. *Clin Orthop Relat Res*. 2005;441:115–124.
48. Moskal JT, Mann III JW. A modified direct lateral approach for primary and revision total hip arthroplasty: a prospective analysis of 453 cases. *J Arthroplasty*. 1996;11:255–266.
49. Higgins BT, Barlow DR, Heagerty NE, Lin TJ. Anterior vs. posterior approach for total hip arthroplasty, a systematic review and meta-analysis. *J Arthroplasty*. 2015;30:419–434.
50. Foissey C, Fauvernier M, Fary C, Servien E, Lustig S, Batailler C. Total hip arthroplasty performed by direct anterior approach - does experience influence the learning curve? *Sicot J*. 2020;6:15.
51. Saberi N, Akhgari M, Bahmanabadi L, Bazmi E, Mousavi Z. Determination of synthetic pharmaceutical adulterants in herbal weight gain supplements sold in herb shops, Tehran, Iran. *Daru*. 2018;26:117–127.
52. Mortazavi SMJ, Moharrami A, Shafiei H, Ebrahimzadeh MH, Karimi M. Unapproved weight gain supplement as a cause of avascular necrosis: a cautionary report. *Arch Bone Jt Surg*. 2019;7:561–565.