KANSAS JOURNAL *of* MEDICINE

Short-Term Radiographic Evaluation of a Tri-Tapered Femoral Stem in Direct Anterior Total Hip Arthroplasty

William G. Messamore, M.D., Ph.D.[1],
Matthew L.G. Vopat, M.D.[1], Elizabeth A. Helsper, M.D.[1],
Andrew J. Bachinskas, M.D.[1], Michelle J. Nentwig, M.D.[1],
Tarun Bhargava, M.D.[1,2]
[1]University of Kansas School of Medicine-Wichita, Department of Orthopaedics, Wichita, KS
[2]Mid-America Orthopedics, Wichita, KS

Received April 30, 2019; Accepted for publication Dec. 12, 2019; Published online March 20, 2020

ABSTRACT

Introduction. Direct anterior approach (DAA) total hip arthroplasty (THA) has become increasingly popular, largely due to utilization of a true internervous and intermuscular plane. However, recent literature has demonstrated an increased rate of femoral implant subsidence with this approach. Hence, different femoral implants, such as the tri-tapered femoral stem, have been developed to facilitate proper component insertion and positioning to prevent this femoral subsidence. The purpose of this study was to evaluate the subsidence rate of a tri-tapered femoral stem implanted utilizing a DAA, and to determine if the proximal femoral bone quality affects the rate of subsidence.

Methods. A retrospective analysis of 155 consecutive primary THAs performed by a single surgeon was conducted. Age, gender, primary diagnosis, and radiographic measurements of each subject were recorded. Radiological evaluations, such as bone quality, femoral canal fill, and implant subsidence, were measured on standardized anteroposterior (AP) and frog-leg lateral radiographs of the hip at 6-week and 6-month postoperative follow-up evaluations.

Results. The average subsidence of femoral stems was 1.18 ± 0.8 mm. There was no statistical difference in the amount of subsidence based on diagnosis or proximal femora quality. The tri-tapered stem design consistently filled the proximal canal with an average of 91.9 ± 4.9% fill. Subsidence was not significantly associated with age, canal flare index (CFI), or experience of the surgeon.

Conclusion. THA utilizing the DAA with a tri-tapered femoral stem can achieve consistent and reliable fit regardless of proximal femoral bone quality. ***Kans J Med 2020;13:51-55.***

INTRODUCTION

Cementless total hip arthroplasty (THA) has emerged as an alternative to cemented systems to improve osseointegration of components and to increase long-term survival of implants.[1] This is particularly important as there has been a recent shift towards younger and higher demand patients undergoing THA. One of the main challenges with cementless stems is achieving solid primary fixation. Stable primary fixation promotes bone ingrowth and facilitates implant stability postoperatively. Additional considerations in cementless systems are preservation of bone stock and reduction of stress-shielding. The primary stability of a cementless femoral stem is affected, not only by the implant design, but also by other factors such as the mechanical quality of the host bone, the presence of gaps around the bone-implant interface, the body weight of the patient, and the size of the implant.[2]

Several surgical approaches can be utilized during THA with direct anterior approach, direct posterior approach, and lateral approach being the most popular.[3-5] Currently, the direct posterior is the most commonly used approach that allows the surgeon excellent visibility of the joint and precise placement of implants. There is decreasing popularity of the lateral approach. Both posterior and lateral approaches necessitate cutting the gluteus muscle and short external rotators, which may result in muscle weakness, postoperative limp, and increased rehabilitation time.

The direct anterior approach (DAA) has become increasingly more popular among arthroplasty surgeons, in large part due to its utilization of a true internervous and intermuscular plane.[6] This surgical technique protects the hip abductors, the posterior capsule, and the short external rotators. Therefore, with proper component placement, the need for postoperative hip precautions is reduced.[7-9] Though some studies have demonstrated favorable early results using the DAA compared to more traditional approaches,[10] recent literature has raised concern for increased risk of femoral stem subsidence.[11]

This concern has led to the more widespread use of bone-preserving stems.[12] Certain stem design features, such as a tri-taper design, have evolved to improve proximal load transfer, reduce the risk of stress-shielding, and decrease implant loosening. This tri-tapered, wedge-shaped stem incorporates mediolateral and anteroposterior longitudinal tapers to transfer compressive load to the bone interface and a lateral-to-medial taper to enhance load transfer to the medial cortex of the proximal femur. Due to their shorter length and curved distal bullet tip, these implants are more easily inserted and positioned through the DAA since they require less proximal surgical exposure than is required for insertion of a longer stem.[13] Early results support the principle of using metaphyseal-anchoring, calcar-guided short stems.[14,15]

The purpose of this study was to evaluate the rate of subsidence of a tri-tapered femoral stem implanted utilizing a DAA and to determine if the proximal femoral bone quality affects the rate of subsidence.

METHODS

A retrospective analysis of 221 consecutive primary THAs performed through an anterior approach by a fellowship-trained orthopaedic surgeon (TB) between July 2014 and January 2016 was undertaken. The study was approved by our institutional review board. Three patients were excluded from the dataset for having implants other than a tri-tapered femoral stem. Five were excluded for having no follow-up imaging, 57 for missing 6-week or 6-month follow-up images, and one patient who developed an early infection postoperatively following IV drug use, leaving a cohort of 155 patients with adequate postoperative radiographs for evaluation (Figure 1).

The study group included all patients who were suitable for primary THA ranging in age from 18 to 91 years and who had surgery performed by the lead surgeon through a DAA with implantation of a tri-tapered femoral stem (DJO TaperFill Hip System). All patients received appropriate perioperative antibiotics and antithrombotic agents. All patients were encouraged to ambulate on postoperative day 1. Patients were also encouraged to be weight-bearing and to discontinue the use of walker or cane as quickly as tolerated.

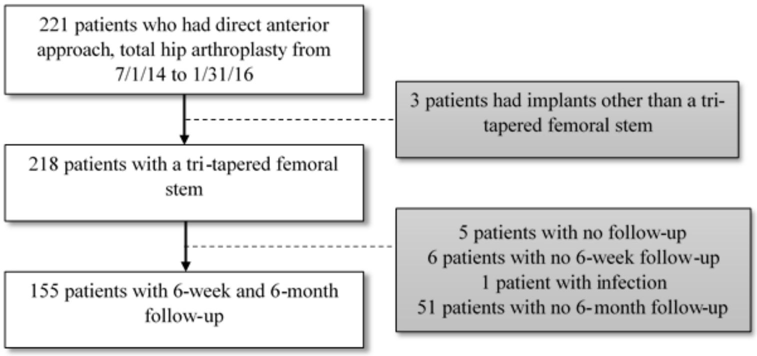

Figure 1. Flow chart defining study cohort, exclusion criteria.

Patient demographic information, such as age, gender, height, weight, body mass index, primary diagnosis, and surgery date, was collected. Radiological evaluation of standardized anteroposterior (AP) and frog-leg lateral radiographs of the hip was done to determine bone quality, femoral canal fill, implant subsidence, and implant alignment preoperatively at 6-weeks and at 6-months postoperative. The radiographs were analyzed by independent examiners who were not involved in the care of the patients.

Proximal Femora Bone Quality. A canal flare index (CFI), defined as the canal width 20 mm above the middle of the lesser trochanter (LT) divided by canal width 60 mm below the middle of the LT on the AP radiograph (Figure 2), was calculated to assess bone quality in the study group. Utilizing the CFI values, each femur was classified based on Dorr femur type. Femora with a CFI > 4.7 were classified as Dorr A bone, CFI in the range of 3.0 - 4.7 as Dorr B bone, and CFI < 3.0 as Dorr C bone.[16,17] Dorr A represents bone with a thicker and stronger cortex than Dorr B, which is stronger than Dorr C.

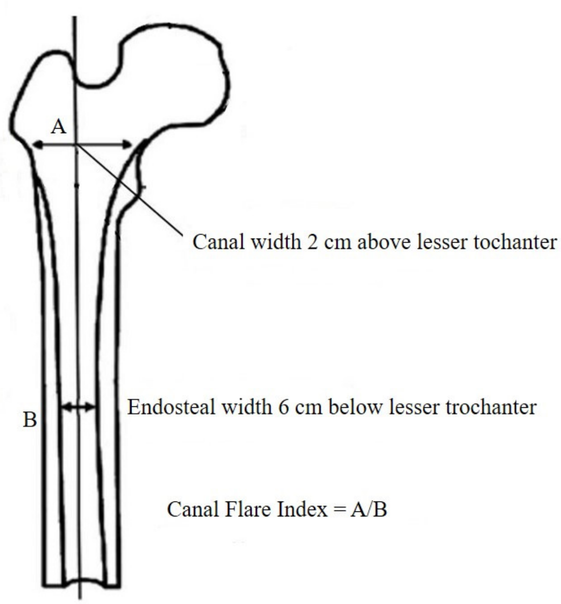

Figure 2. Calculation of the canal flare index.

Femoral Canal Fill. Four locations on the femur identified on the anteroposterior (AP) radiograph were used to measure canal fill: (A) at the neck cut, (B) 10 mm above the LT, (C) at the LT, and (D) 60 mm below the LT (Figure 3A), as previously described by Grant et al.[18] The canal width and implant width were recorded at each location, with percent fill at each location calculated as implant width divided by canal width. Total average fill was calculated as the average percent fill at all four locations. A line was extended from the lateral cortex to eliminate the flare of the canal at the two proximal locations.

Implant Subsidence. The distance (in millimeters) of the distal femoral stem relative to the lesser trochanter (T-T Distance) was measured on AP radiographs at 6-week and 6-month clinical follow-up (Figure 3B). The implant subsidence was calculated as the difference between these measurements at 6 weeks and 6 months after surgery. Subsidence of 3 mm was defined as significant as previously described by Albers et al.[14]

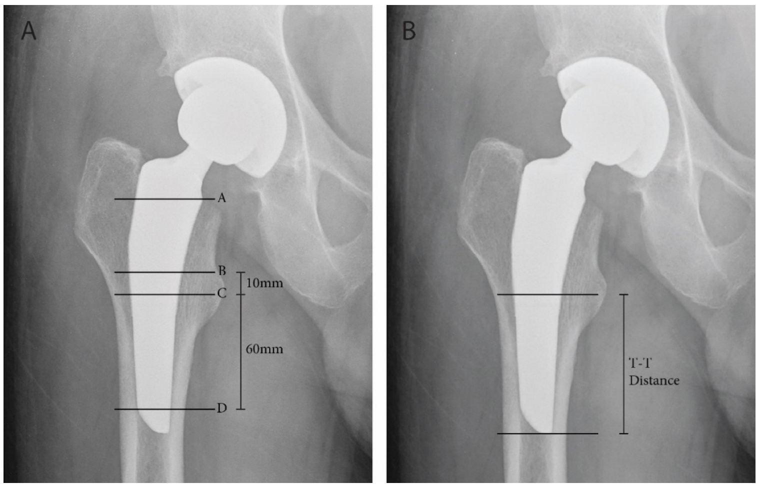

Figure 3. (A) Four locations on the femur used to measure canal fill. (B) T-T distance (in millimeters) of the distal femoral stem relative to the lesser trochanter.

Data Analysis. Descriptive statistics included summarizing all variables based on the type of data collected with a measure of central tendency and a measure of variability. Categorical data were summarized with frequencies and percentages. Continuous data were tested for normality using histograms and the Kolmogorov-Smirnov exact test. When data passed the assumption of normality, they were summarized with means and standard deviations. Bivariate associations were assessed with the Chi-square, Mann-Whitney, and Kruskal-Wallis tests. Paired data were evaluated using the paired t-test, or nonparametric Wilcoxon signed-ranks exact test and Friedman test. Because some data were not normally distributed, nonparametric Spearman's rho was used to assess correlations. All tests were conducted with IBM SPSS Statistics, version 23.

RESULTS

Of the patients in our cohort, 55% (85/155) were female and 45% (70/155) were male. The mean age was 63.7 ± 12 years (range 18 - 91). The majority of our cohort (95%) was non-Hispanic Caucasian. Eighty-three percent (128/155) of patients had a diagnosis of primary osteoarthritis, 11% (17/155) had osteonecrosis, 2% (93/155) had fracture, 3% (5/155) had dysplasia, and 1% (2/155) had post-Perthes deformity. CFI analysis revealed only one patient had Dorr A bone, 76 had Dorr B bone, and 78 had Dorr C (Table 1).

The mean subsidence of the study cohort was 1.18 mm ± 0.83 (0.0 - 3.1) with only 26% (26/155) femoral stems having subsided more than 2 mm. The mean subsidence for patients treated for primary osteoarthritis was 1.18 ± 0.84 mm, 1.12 ± 0.70 mm for osteonecrosis, 1.27 ± 1.08 mm for fracture, 1.34 ± 0.59 mm for dysplasia, and 1.35 ± 1.05 mm for post-Perthes deformity (Table 2).

Table 1. Demographics data for patients included in the study.

Race	No. (%)	**Diagnosis**	No. (%)
White	148 (95.48)	Primary	128 (82.58)
Black	5 (3.22)	Osteonecrosis	17 (10.96)
American Indian	1 (0.64)	Fracture	3 (1.93)
Hispanic	1 (0.64)	Dysplasia	5 (3.22)
		Perthes	2 (1.29)
Age		**Proximal Femora Classification**	
Mean ± SD (yr.)	63.69 ± 12 (18 - 91)		No. (%)
	No. (%)	Dorr A	1 (0.64)
≤ 55 years	32 (20.64)	Dorr B	76 (49.03)
55 - 64 years	51 (32.90)	Dorr C	78 (50.32)
65 - 74 years	40 (25.80)	Mean CFI ± SD	3.01 ± 0.57 (1.61 - 5.02)
≥ 75 years	32 (20.64)		
Sex			
Male	70 (45.16)		
Female	85 (54.83)		

Since the Kolmogorov-Smirnov exact test showed that subsidence was not normally distributed (k = 0.116, p = 0.029), the data set was evaluated using the nonparametric Wilcoxon signed-ranks exact test. When the latter statistical test was applied, no statistically significant differences were found between subsidence and other variables, including gender (p = 0.526), race (p = 0.246), Dorr grade (p = 0.580), or etiology (p = 0.861).

As shown in Table 3, the tri-tapered stem design filled most of the femoral canal in all four regions of the AP radiographs. In the proximal canal, averaging the three most proximal measurements, the tri-tapered stem percent fill was approximately 92 ± 5% at 6 weeks and 91 ± 5% at 6 months. The most distal measurement of 60 mm below the lesser trochanter averaged 87 ± 9% at 6 weeks and 87 ± 8% at 6 months.

Table 2. Average subsidence of femoral stem from 6-week to 6-month follow-up.

Subsidence			**Average Subsidence Based on Diagnosis**		
Mean ± SD	1.18	± 0.83 (0.0 - 3.1)	Primary ± SD	1.18	± 0.84 (0.0 - 3.1)
	No. (%)		Osteonecrosis ± SD	1.12	± 0.70 (0.1 - 2.9)
≤ 1 mm	82 (52.90)		Fracture ± SD	1.27	± 1.08 (0.5 - 2.1)
1 - 2 mm	47 (30.32)		Dysplasia ± SD	1.34	± 0.59 (0.5 - 2.1)
2 - 3 mm	24 (15.48)		Perthes ± SD	1.35	± 1.05 (0.3 - 2.4)
> 3 mm	2 (1.29)				
Average Subsidence Based on Sex					
Male ± SD	1.13	± 0.82 (0.0 - 3.1)			
Female ± SD	1.21	± 0.83 (0.0 - 3.0)			

Table 3. Calculated percentage fill of femoral stems from 6-week to 6-month follow-up.

Percent Fill at 6-Weeks Post-Operative		
Neck Cut ± SD	91.6%	± 5.6% (73.3% - 100.0%)
LT + 10 mm ± SD	92.3%	± 4.4% (76.7% - 100.0%)
LT ± SD	91.73%	± 4.75% (71.25% - 100.0%)
LT - 60 mm ± SD	86.7%	± 8.63% (55.7% - 100.0%)
Percent Fill at 6-month Post-Operative		
Neck Cut ± SD	92.1%	± 5.4% (70.5% - 100.0%)
LT + 10 mm ± SD	91.3%	± 4.6% (69.7% - 100.0%)
LT ± SD	90.5%	± 4.8% (75.5% - 100.0%)
LT - 60 mm ± SD	86.9%	± 8.1% (53.5% - 100.0%)

When analysis was performed with CFI, age, and surgeon experience as covariates, no correlation was found with increasing subsidence (Figure 4). Correlation comparison was executed by Spearman's rho ranking test (Table 4). Subsidence was not significantly associated with age ($\rho = 0.029$), CFI index ($\rho = 0.015$), or experience of the surgeon ($\rho = -0.078$). No significant association was found between increasing age and decreasing CFI ($\rho = -0.155$).

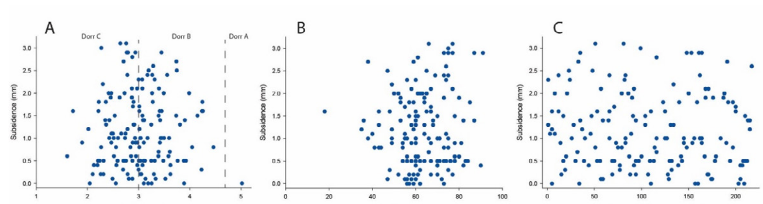

Figure 4. Scatter plots with canal flair index, age, and surgeon experience as covariates.

Table 4. Spearman's rho correlations with canal flair index, age, and surgeon experience.*

Characteristics	Subsidence	Age
Age	0.029	--
CFI Index	0.015	-0.155
Experience Ranking	-0.078	--

*The sign of the Spearman correlation indicates the direction of association between the independent and the dependent variable. If positive the two variables tend to increase in relation to each other. If negative the two variables are inversely related. A correlation of zero indicates the two variables are independent of each other. As the two variables become more dependent the correlation will be closer to 1 or -1. Dashes indicate variables that were not tested for association.

DISCUSSION

The DAA has become more popular among surgeons and patients due to its true internervous and intermuscular surgical approach.[6] However, as the DAA has become more widely adopted, some authors have suggested that the approach itself is a risk factor for early femoral stem failure of cementless THA. In their series of revision THA, Meneghini et al.[11] observed the need for revision of a loose femoral stem was 0.29 times more likely with a direct anterior approach than with a posterior approach when controlling for other independent variables. This increase in aseptic failures was attributed to surgeon inexperience, intraoperative femur fractures, and procedure difficulty.

In our study of 155 consecutive patients receiving THA through a DAA, there were no cases of clinically significant femoral stem subsidence with an average subsidence of 1.18 ± 0.83 mm. There was no statistically significant subsidence based on gender, age, or diagnosis. A strength of our study was that we analyzed a consecutive series of patients thereby eliminating any selection bias. Also, the hip reconstruction was standardized among our cohort, as all patients had the same DAA and surgical implants.

The variability in proximal femora anatomy and mechanical quality of host bone is difficult to quantify. CFI was used as a way to measure and categorize our study population objectively according to the Dorr classification.[16,17] Whereas other publications looking at femoral stem subsidence have excluded patients with Dorr C bone, a strength of our study was inclusion of these patients. There was no correlation between subsidence and Dorr classification (p-value = 0.580) or between subsidence and CFI (rho value = 0.015). Biomechanically, we would expect to see an increase in subsidence with an increase in CFI (suggesting more osteoporotic bone), but our study did not detect that association.

Surgeon inexperience has been implicated as a cause for early failure of THA performed through a DAA.[10] While the primary surgeon in our study had performed over 1,000 anterior total hip arthroplasties, our series included patients immediately following a transition to a newer implant. We attempted to detect a change in outcomes based on familiarity with the new implant by analyzing the cases consecutively. There was no correlation between experience with the new implant and risk of subsidence. The implant used had the advantage of being designed with the DAA in mind and was shorter than other implants on the market and incorporated a distal flare of the stem to aid in implantation through a DAA affecting our distal canal fill percentages. The stem filled the proximal femoral canal reliably with 91.88 ± 4.94% fill. In smaller femurs, the measurements of distal fill occasionally would include the flare and give artificially lower percentage of distal fill when using the previously described method of Grant et al.[18] There were no cases of femoral periprosthetic fractures in our series.

Limitations of this study included the retrospective nature of our cohort. Fifty-one patients were excluded from our study because their follow-up radiographs were not available to us for review. Patients referred to our practice by primary providers from outlying areas and insured by various healthcare plans frequently had postoperative radiographs taken at outside facilities to which we had limited access. Nevertheless, we were able to evaluate 70% of our patients in this consecutive series. We were also limited in our access to immediate postoperative imaging and could have missed very early subsidence in the first six weeks, despite no patient having clinically significant subsidence during this period.

Though using a new implant, the primary surgeon in this study was experienced in the surgical technique and beyond the "learning curve" that has been well described to correlate with early complications. Therefore, the results of this study may not be representative of that for more inexperienced surgeons. The results of Meneghini et al.[11] likely included many surgeons early in their "learning curve" as that study included 69 different referring surgeons.

In conclusion, the results from this study provide evidence that a THA utilizing the DAA and a tri-tapered femoral stem can achieve consistent and reliable fit regardless of proximal femoral bone quality.

REFERENCES

1 Nho SJ, Kymes SM, Callaghan JJ, Felson DT. The burden of hip osteoarthritis in the United States: Epidemiologic and economic considerations. J Am Acad Orthop Surg 2013; 21:S1-6. PMID: 23818185.

2 Viceconti M, Brusi G, Pancanti A, Cristofolini L. Primary stability of an anatomical cementless hip stem: A statistical analysis. J Biomech 2006; 39(7):1169-1179. PMID: 15927191.

3 Baker AS, Bitounis VC. Abductor function after total hip replacement. An electromyographic and clinical review. J Bone Joint Surg Br 1989; 71(1):47-50. PMID: 2915004.

4 Horwitz BR, Rockowitz NL, Goll SR, et al. A prospective randomized comparison of two surgical approaches to total hip arthroplasty. Clin Orthop Relat Res 1993; 291:154-163. PMID: 8504594.

5 Masonis JL, Bourne RB. Surgical approach, abductor function, and total hip arthroplasty dislocation. Clin Orthop Relat Res 2002; 405:46-53. PMID: 12461355.

6 Post ZD, Orozco F, Diaz-Ledezma C, Hozack WJ, Ong A. Direct anterior approach for total hip arthroplasty: Indications, technique, and results. J Am Acad Orthop Surg 2014; 22(9):595-603. PMID: 25157041.

7 Siguier T, Siguier M, Brumpt B. Mini-incision anterior approach does not increase dislocation rate: A study of 1037 total hip replacements. Clin Orthop Relat Res 2004; 426:164-173. PMID: 15346069.

8 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. PMID: 16330993.

9 Oinuma K, Eingartner C, Saito Y, Shiratsuchi H. Total hip arthroplasty by a minimally invasive, direct anterior approach. Oper Orthop Traumatol 2007; 19(3):310-326. PMID: 17728988.

[10] Meermans G, Konan S, Das R, Volpin A, Haddad FS. The direct anterior approach in total hip arthroplasty: A systematic review of the literature. Bone Joint J 2017; 99-B(6):732-740. PMID: 28566391.
[11] Meneghini RM, Elston AS, Chen AF, Kheir MM, Fehring TK, Springer BD. Direct anterior approach: Risk Factor for Early Femoral Failure of Cementless Total Hip Arthroplasty: A Multicenter Study. J Bone Joint Surg Am 2017; 99(2):99-105. PMID: 28099299.
[12] Lombardi AV Jr, Berend KR, Adams JB. A short stem solution: Through small portals. Orthopedics 2009; 32(9): pii: orthosupersite.com/view.asp?rID=42833. PMID: 19751018.
[13] Ahmed MM, Otto TJ, Moed BR. Anterior total hip arthroplasty using a metaphyseal bone-sparing stem: Component alignment and early complications. J Orthop Surg Res 2016; 11:46. PMID: 27106260.
[14] Albers A, Aoude AA, Zukor DJ, Huk OL, Antoniou J, Tanzer M. Favorable results of a short, tapered, highly porous, proximally coated cementless femoral stem at a minimum 4-year follow-up. J Arthroplasty 2016; 31(4):824-829. PMID: 26411395.
[15] Kutzner KP, Pfeil D, Kovacevic MP, et al. Radiographic alterations in short-stem total hip arthroplasty: A 2-year follow-up study of 216 cases. Hip Int 2016; 26(3):278-283. PMID: 27102556.
[16] Noble PC, Alexander JW, Lindahl LJ, Yew DT, Granberry WM, Tullos HS. The anatomic basis of femoral component design. Clin Orthop Relat Res 1988: 235:148-165. PMID: 3416522.
[17] Issa K, Pivec R, Wuestemann T, Tatevossian T, Nevelos J, Mont MA. Radiographic fit and fill analysis of a new second-generation proximally coated cementless stem compared to its predicate design. J Arthroplasty 2014; 29(1):192-198. PMID: 23706811.
[18] Grant TW, Lovro LR, Licini DJ, Warth LC, Ziemba-Davis M, Meneghini RM. Cementless tapered wedge femoral stems decrease subsidence in obese patients compared to traditional fit-and-fill stems. J Arthroplasty 2017; 32(3):891-897. PMID: 27793497.

Keywords: hip arthroplasty, hip prosthesis, diagnostic imaging, orthopedic surgery