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Original research

Quality of the femoral cement mantle in total hip arthroplasty using the direct anterior hip approach

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ABSTRACT

Background: Limited literature exists concerning the femoral cement mantle quality that can be achieved through an anterior approach in total hip arthroplasty (THA). We radiologically evaluated the quality and thickness of the femoral cement mantle in patients undergoing THA utilizing the direct anterior approach (DAA).
Methods: Immediate postoperative anteroposterior and lateral radiographs of 116 consecutive patients who underwent hybrid or fully cemented THA using the DAA and cemented Quadra-C stem (Medacta, International, SA, Switzerland) were assessed by 2 arthroplasty surgeons blinded to the study. Surgical indications were hip osteoarthritis or subcapital hip fracture. The cement mantle and stem alignment were evaluated using the Barrack classification and Khalily methods, respectively. After calibration of radiographs, the thinnest part of the cement mantle per Gruen zone was recorded. Parameters were compared between obese and nonobese patients.
Results: Agreement between raters was substantial for the cement quality in anteroposterior (k = 0.707, $P \leq .001$) and moderate for lateral radiographs (k = 0.574, $P \leq 001$). The cement mantle was graded A in 39.25%, B in 53.0%, and C in 7.75% of anteroposterior radiographs and similarly for lateral radiographs (40.1% A, 51.75% B, 9.5% C). 93% of stems had neutral alignment. The mean thinnest cement mantle ($P =$ .237) and incidence of inadequate cement mantle (<2 mm) per zone ($P = .431$) were comparable between Gruen zones. The cement mantle quality ($P = .174$) and inadequacy ($P > .05$) and stem alignment ($P = .652$) were comparable between obese and nonobese patients.
Conclusions: DAA enables correct implantation and effective cementation of straight femoral stems. A high-quality cement mantle can be achieved using DAA even in obese patients.

Introduction

The direct anterior approach (DAA) is a well-established muscle-sparing approach to the hip joint, which is used increasingly worldwide [1]. It can be performed with or without use of a traction table in the lateral or supine position [2]. Total hip arthroplasty (THA) utilizing the DAA is associated with favorable functional outcomes, especially during the initial postoperative period [2,3].

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One aspect of this technique that has been questioned is the ability of the surgeon to adequately approach the femoral canal [4,5]. A few DAA studies have recorded a high rate of complications and improper femoral component placement, with the majority being mainly during the learning curve of the surgeon [6-8].

The outcomes of cemented THA and the integrity of the femoral cement mantle using the DAA have not been reported in large numbers [2]. Consequently, it is unclear whether the DAA technique detrimentally affects the femoral stem cement mantle integrity. The limited literature available suggests the DAA is probably related to a higher rate of deficiency of the cement mantle compared with the posterior approach [9]. However, the cement mantle quality is recognized as being highly associated with the longevity of a prosthesis [9,10]. Although some degree of uncertainty still exists, the initial thickness and homogeneity of the cement mantle, as well as the presence of deficiencies, are critical in the process of aseptic loosening [11].

This study aimed to radiologically evaluate the quality of femoral stem cementation in a consecutive series of patients undergoing THA utilizing the DAA. Secondary aims were to estimate the alignment of the triple tapered design stem used in all cases and the thickness of cement mantle in different zones of the femur. The cement mantle quality and thickness, and implant alignment were compared between obese and nonobese patients to determine whether this affected outcomes.

Material and methods

This retrospective single-blinded study assessed the quality of the cement mantle on the immediate postoperative radiographs of 116 consecutive patients undergoing primary hybrid THA using the DAA. The study was performed according to the World Medical Association Declaration of Helsinki of 1964 as revised in 1975 and 2000. All patients involved in the study gave informed consent.

The appropriate cases were identified using our hospital's administrative and operative theater records over the last 3 years, between January 2016 and January 2019. During the operative period, the senior surgeon had been unaware that his series was too be analyzed. All procedures were carried out in the supine position using 'on table' technique with the AMIS Mobile Leg Positioner (Medacta, International). Preoperative femoral templating was performed on anteroposterior (AP) radiographs to estimate the optimal size of the stem permitting a minimum cement mantle of 2 mm. In all cases, the cemented Quadra-C stem (Medacta, International, SA, Switzerland) was implanted. The vast majority of patients (113/116) received the uncemented Versafitcup (Medacta, International, SA, Switzerland); 3 of them received a cemented Apricot cup (Medacta, International, SA, Switzerland). Included cases were adults with end-stage hip osteoarthritis (101/116) or a subcapital hip fracture (15/116). Good-quality AP and cross-table lateral radiographs where the cement mantle was fully visualized throughout the length of the femoral implant stem on both views were the inclusion criteria. Two cases were excluded from our series because the cement mantle was not fully visualized in the lateral radiographs. The exclusion criteria involved revision THA or any previous surgery of the hip, a different type of implant (other than Quadra-C stem), and cases with inadequate imaging techniques. A senior hip and pelvis orthopedic surgeon (P.C.) performed all the surgical procedures.

Surgical procedure

All cases underwent the same procedure commencing with a standard 6-10 cm straight skin incision performed at 2 cm lateral and distal to the anterior superior iliac spine toward the lateral tibial condyle (Gerdy's tubercle). Once the interval between the tensor fascia lata and sartorius was developed, the rectus femoris and iliocapsularis were carefully internally mobilized, and the ascending branches of lateral circumflex femoral vessels were ligated. The hip capsule was then opened in a Π-shaped incision, and osteotomy and removal of the femoral neck was performed. After preparation of the acetabulum, the cup was implanted.

Attention was then turned to the femur. The posterior capsule behind the fossa piriformis was released without cutting any of the pelvitrochanteric tendons (Fig. 1). Any remnant of the cortical neck bone close to the piriformis fossa was carefully excised. A specialized femoral retractor (Medacta, International) was placed beneath the greater trochanter to assist in lifting the femur; another retractor was positioned in the calcar region to facilitate hip abduction while the assistant surgeon pressed the femur lightly to adduction, to further assist the view to the proximal femur. After hyperextension and external rotation of the leg using the dedicated leg positioner, the femoral canal was prepared conventionally; the largest available broach corresponding, the preoperative planning, was used taking care to preserve a layer of cancellous bone to facilitate cement interdigitation. We did not remove the extra cancellous bone from the posterior greater trochanteric region to facilitate posterior canal entry. We performed a third-generation cementing technique utilizing pulsed lavage, application of a cement restrictor, and drying the femoral canal. Palacos cement (Heraeus Medical, Wehrheim, Germany) was inserted with a gun in a retrograde fashion and pressured with a proximal femoral silicon seal; the Quadra-C stem (one size smaller than the final broach) was then inserted, and appropriate pressure was proximally applied till the final polymerization and cooling of the cement.

Radiologic assessment and implant and patient characteristics

Demographics including age, sex, and BMI, as well as the size of the implants, were recorded. One-month postoperative standard AP radiographs centered over the pubic symphysis with the hips in internal rotation (15°) including whole length and width of the femoral stem and cross-table lateral (CTL) radiographs were used. Two fellowship-trained arthroplasty surgeons, blinded to the aim of the study, evaluated the postoperative radiographs. They had not been involved in any of the surgical procedures and they did not

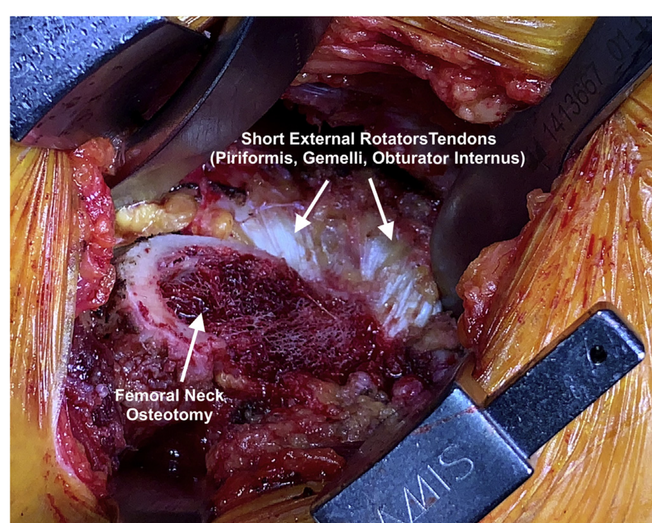

Figure 1. An intraoperative picture of a direct anterior approach demonstrating the femoral neck osteotomy and intact tendons of short external rotators.

know the chief surgeon and the approach used. The raters were instructed to asses the quality and thickness of the cement mantle in Gruen zones [12] around the stem and the alignment of the femoral stem on AP radiographs. Besides, the CTL radiographs were used to further evaluate the cement mantle quality. The alignment of the stem and the cement mantle thickness and quality were compared between obese (>30 kg/m^2) and nonobese patients.

The quality of the cement mantle was evaluated with the four-grade Barrack classification [13]. Grade A relates to a perfect cement filling of canal and absence of radiolucencies between the cement mantle and bone. Grades B and C involve up to 50% or 50%-99% of radiolucencies in the bone-cement interface, respectively. Grade D demonstrates 100% radiolucency or the absence of cement distal to the tip of the femoral stem.

The stem alignment in the frontal plane was assessed with the Khalily method that assesses the angle between the medial endosteal cortex of the femoral shaft and the long axis of the femoral stem [14]. An angulation greater than 5 degrees was considered as varus positioning (Fig. 2a and b). We calibrated the radiographs using the known length of stem that was estimated from the upper lateral part to the tip of the stem. The thickness of the cement mantle was assessed in the 7 zones of Gruen in the AP radiograph [12]. The thinnest part of the cement mantle in each zone was recorded. An adequate cement mantle was defined as at least 2 mm [1,15]. We did not evaluate the thickness of the cement mantle at the region below the tip of the stem because of the regular use of cement restrictors.

Statistical analysis

The Fleiss' kappa (κ) coefficient was used to evaluate the inter-rater agreement between the 2 raters [16]. Landis and Koch's criteria were used to categorize the agreement between raters [17]. We used the χ^2 test to compare the quality of cement mantle and the varus alignment of stems between obese and nonobese patients as well as the proportion of inadequate cement mantles in different zones. One-way ANOVA was used to compare the mean thinnest cement mantle between various cement zones in patients.

Standard statistical methods were used for descriptive statistics. The normality of data distribution was tested according to the Kolmogorov-Smirnov or Shapiro-Wilk test. The hypothesis of equality of means was discarded when the probability (p) of a type I error was ≤5%. All statistical tests were two-tailed. Analyses were performed with the use of the SPSS statistical software (version 12, Chicago, IL, USA).

Results

A total of 116 AP and CTL radiographs were rated. There were 59 men and 57 women with a mean age of 76 ± 8.8 years. Twenty-two percent of the patients had a BMI higher than 30 m/kgr^2. The first, second, and third were the most frequently used Quadra stem sizes (Table 1). Demographics of the patients and implant characteristics are depicted in Table 1.

There was a substantial agreement between raters in the assessment of cement mantle quality of AP radiographs (k = 0.707, $P \leq .001$) and moderate agreement between them in CTL radiographs (k = 0.574, $P \leq 001$). The raters graded 19 AP and 28 CTL radiographs differently. Overall, the cement mantle was categorized as grade A in 39.25%, as grade B in 53.0%, and as grade C in 7.75% of the AP radiographs. Concerning the CTL radiographs, there were 40.1% of cases with grade A cement mantles, 51.75% with grade B, and 9.5% with grade C. Table 2 demonstrates the cement mantle rating according to the Barrack classification in both AP and CTL radiographs. Both raters modified the grade of the cement mantle quality from the AP to CTL radiographs in 37 (31.9%) of cases. In most cases, the femoral stem alignment in the AP radiograph was neutral; 93% aligned in neutral, and 7% in varus. In detail, there were 68.1% of stems with 0°-3° angle, 25% with 3°-5°, 5.2% of stems with 5°-7°, and 1.7% of stems with angle greater than 7°. The mean

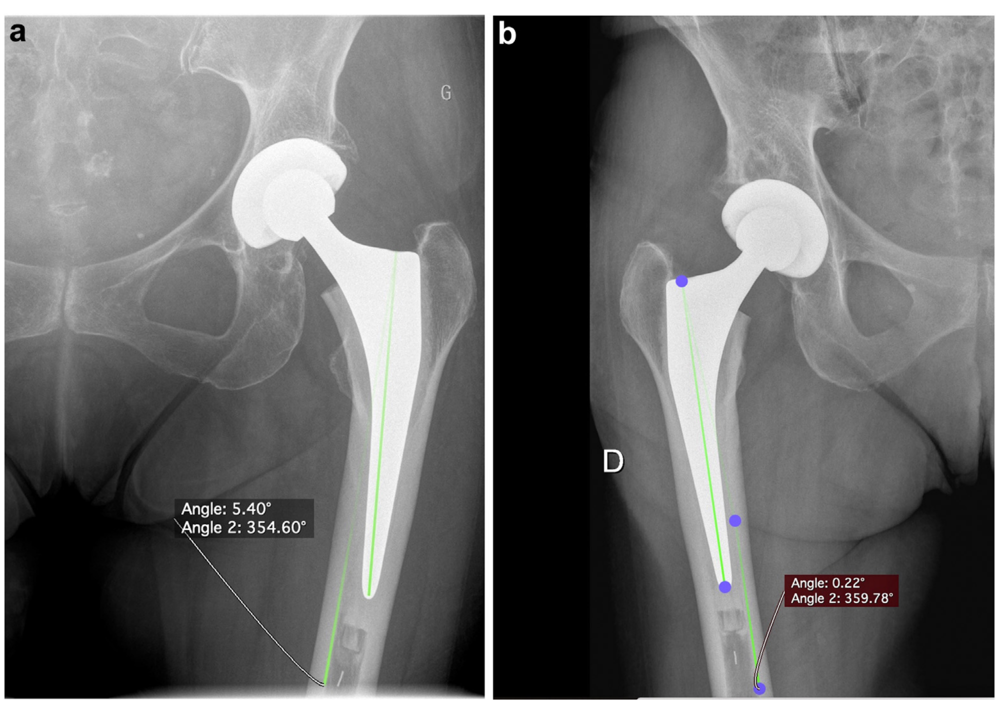

Figure 2. (a). Immediate postoperative right anteroposterior hip radiographs with the stem in the neutral position (Khalily angle: 0.22°) and (b) immediate postoperative left anteroposterior hip radiographs with the stem in the varus position (Khalily angle: 5.40°). D, Droit (right).

Table 1
The demographics, preoperative baseline characteristics, and implant data of the patients.

Parameters	Values
Number[b]	116
Age (years)[a]	76.04 ± 8.8 (52-96)
Sex[c]	
Male	59 (50.9)
Female	57 (49.1)
Height[a]	166.9 ± 8.5 (140-185)
Weight[a]	69.7 ± 19.0 (40-140)
BMI (kg/m^2)[a]	24.8 ± 5.8 (14.7-45.2)
BMI less than 30 kgr/m^2[c]	94 (81)
BMI more than 30 kgr/m^2[c]	22 (19)
ASA grade[c]	
I	61 (52.6)
II	48 (41.4)
III	7 (6.0)
Operated side[c]	
Right	62 (53.4)
Left	54 (46.6)
Stem size[c] (Quadra stem)	
0	6 (5.2)
1	27 (23.3)
2	43 (37.1)
3	22 (19)
4	8 (6.9)
5	8 (6.9)
6	1 (0.9)
7	1 (0.9)

BMI = body mass index, ASA = American Society of Anesthesiologists score.
[a] The values are given as the mean with the standard deviation and the range in parentheses.
[b] The values are given as raw numbers.
[c] The values are given as raw numbers with the percentages in parentheses.

thinnest cement mantle was recorded in the first and third zones of Gruen (Table 3). However, the mean thinnest cement mantle of each zone did not differ significantly between zones (one-way ANOVA, $P = .237$). The incidence of an inadequate cement mantle (<2 mm) for each zone did not differ significantly between the various zones (χ^2 test, $P = .431$).

The cement mantle quality did not differ significantly between obese and nonobese patients (χ^2 test, first rater AP view $P = .174$, lateral $P = .362$, second rater AP view $P = .625$, lateral $P = .603$). The percentage of varus alignment of stems and the Khalily score were comparable between obese and nonobese patients (χ^2 test, $P = .652$ and Mann-Whitney test, $P = .316$, respectively). The incidence of inadequate cement mantles (<2 mm) was similar between obese and nonobese patients (χ^2 test, zone 1, $P = .177$/ zone 2, $P = .913$/ zone 3, $P = .603$/ zone 5, $P = .992$/ zone 6, $P = .352$/ zone 7, $P = .328$).

Discussion

This study is the largest case series we are aware of that has evaluated the quality and adequacy of the femoral cement mantle achieved during hybrid or cemented THA through the DAA. Our results demonstrated that adequate cement mantle and alignment

Table 2
Grading of the cement mantle in anteroposterior and lateral radiographs according to Barrack classification.

Grade	Rater 1	Rater 2	Rater 1	Rater 2
	Anteroposterior		Lateral	
A	48 (41.4)	43 (37.1)	50 (43.1)	43 (37.1)
B	61 (52.6)	62 (53.4)	59 (50.9)	61 (52.6)
C	7 (6)	11 (9.5)	7 (6)	12 (10.3)
D	0	0	0	0

Table 3
The characteristics of the thinnest cement mantle in different zones of Gruen.

Zones	Mean ± SD	Min-Max	% (<2 mm)
Zone 1	2.84 ± 0.94	0-5.9	16 (13.7%)
Zone 2	3.21 ± 2.09	0.1-23	15 (12.9%)
Zone 3	2.9 ± 1.72	0.7-19	17 (14.6%)
Zone 5	3.14 ± 2.15	0-23	21 (18%)
Zone 6	3.33 ± 1.9	0.8-21.3	10 (8.6%)
Zone 7	3.06 ± 1.07	0-6	14 (12%)

The mean and the range of thinnest cement mantle are depicted in the first and second columns. The third column demonstrates the percentage of patients having an inadequate cement mantle (<2 mm) in each zone of Gruen.

of the stem were achieved in more than 90% of the patients undergoing THA through the DAA. The lower mean thinnest cement mantle was recorded in the first and third zones of Gruen; however, the mean thinnest cement mantle was comparable between the zones. The quality of cement mantle and stem alignment was not affected by the patient BMI.

The cement mantle quality is considered critical for the longevity of THA implants [9,18]. However, the optimal thickness of the cement mantle around the femoral stem in THA remains controversial [18,19]. A mantle thickness between 2 and 5 mm is deemed as adequate to achieve satisfactory long-term clinical and radiological outcomes [20,21]. Cement mantles thinner than 2 mm are at higher risk of cement fractures [20,22] that may allow wear particles to pass to the bone-cement interface [20,23], leading to osteolysis and clinical failure [20,23,24]. In contrast, femoral stems that have been implanted line to line with the Kerboull stem and thin cement mantles (French paradox) demonstrated excellent long-term survival at 14 years [18,19]. As a result, the clinical significance of the thin cement mantles with polished tapered designs is controversial and probably more crucial for failure during the second decade where a lot of debris and wear have been accumulated [19,25]. Besides, even when a line to line cementation aims to achieve a thin cement mantle, this is usually thicker than 2 mm [26]. In our study, the mean cement mantle thickness was greater than 2 mm in each Gruen zone, with more than 90% of the mantles graded as type A and B.

The thickness of the cement mantle is dependent on several parameters. The anatomy of the femoral bone [20], the surgical approach [2], the design and size of implant [27], the cementing technique [20], use of a centralizer [28], the somatometric patient characteristics [29], the experience of the surgeon, and choice of the appropriate instruments [21] are important to achieve a cement mantle thickness greater than 2 mm.

The role of the surgical approach in obtaining an adequate cement mantle and implant positioning in cemented THA has not been extensively studied. A recent randomized controlled trial demonstrated minor differences in the cement mantle characteristics and implant positioning between 2 groups of patients undergoing cemented THA that was performed through a mini anterior or direct lateral approach [1]. Another randomized controlled trial cadaveric study evaluated the integrity and quality of the cement mantle after implantation of the Exeter stem through the standard anterolateral or mini-invasive anterior approach. Although this straight stem has to be introduced in an angulated fashion during the anterior approach, the quality and thickness of the cement mantle were not compromised [21]. MacPherson et al. [20], however, showed that the use of Exeter stem and posterior approach minimized the risk of thin cement mantles compared with the anterolateral (transgluteal) approach. In this prospective comparative multisurgeon study, the Barrack grading and the positioning of implants did not differ between approaches, but the posterior approach was associated with significantly thicker cement mantles. Regardless of the approach and stem, there was a high risk of thin cement mantles in zones 8 and 9 [20]. In our study, the thinnest cement mantles were recorded in the first and third zones of Gruen. This may be attributed to the surgical approach and the angulated movement of insertion of the stem during the DAA.

The access to the hip joint through the DAA is performed through a true internervous and intermuscular plane, limiting the tendon and muscle damage [1]. Opposition to the DAA has been generated out of some studies reporting greater difficulty accessing the femur with higher femoral complications and greater complications during the learning curve [30]. In our series, the femur was approached and elevated with minimal releases of the capsule around the greater and lesser trochanter, but no release of the short external hip rotators. Once the femur was elevated, an angulated position of the femoral implant was necessary to introduce the stem into the canal [21]. This maneuver, while important, can cause passage of the tip of the femoral stem close to the lateral cortex, compromising the quality of the cement mantle in the bone-cement interface [21]. In our study, although the thinnest cement mantle was recorded on the first and third zones of Gruen, the quality of cement mantle was not compromised, and a minimal number of defects were recognized in the lateral cortex.

In our study, there were only a very limited number of stems implanted in a varus position (7%), although the angulated position for stem introduction during DAA has been accused of higher risk of varus stem implantation compared to other approaches [21]. Our results indicate that a favorable position is achievable with the DAA surgical technique. However, we recognize comparison of results for different approaches should be taken with care. The position of the stem is multifactorial depending on various parameters as the radiologic method used to evaluate, patients' somatometric characteristics, the design and size of the implant, femoral bone anatomy, surgical approach, and experience of the surgeon. Future studies that control for these factors would allow appropriate comparison of surgical approaches. Malalignment between the femoral stem and the femoral intramedullary axis is of paramount importance in forming a deficient cement mantle. We suggest implant alignment should be evaluated not only on AP but also lateral radiographs, as used in our method. There is a tendency to perform only AP radiographs after THA. Sanghrajka et al. [9] showed that 50% of studied defects were identified on lateral radiographs. By contrast, if no true lateral radiographs have been performed, the danger of thin cement mantles is underrated [24]. In our study, we used the available CTL radiographs to assess the cement mantle quality. The thickness of the cement mantle was not evaluated because true lateral radiographs are not part of the standard postoperative radiographs used in our institution.

The type and design of the stem are also crucial to achieve an ideal cement mantle. Studies on straight Exeter stems reported that almost 25% of the surface of the stem was related to cement mantle thinner than 2 mm [21,31]. In our study, the mean thinnest cement mantle was greater than 2 mm in all cement zones; the percentage of inadequate cement zones ranged between 8.6% and 18%. The Quadra-C stem is a stainless-steel high nitrogen stem with a polished mirrored surface for correct interaction with the cement mantle and rounded edges to avoid peak stresses within the mantle [32]. This straight stem has a triple tapered design and a broader proximal part in crosssection, coming closer to the femoral cortex to the first and seventh Gruen zones, giving rotational stability and less space for the cement mantle in these regions [32]. Our study reported the mean thinnest cement mantles in the first and third Gruen zones but not in the seventh; this may be attributed to the femoral anatomy of the involved patients.

The effect of muscularity or obesity when using a specific surgical approach on the alignment of implants and quality of cement mantle has not been clarified yet. It is supported that the higher BMI, especially in muscular patients, may lead to more anterior broaching and sagittal malalignment of the stem. Although there are concerns that DAA cannot be performed in obese patients [33], MacPherson et al. [20] did not confirm these findings. In our study, not only hybrid THA was feasible through DAA in every patient but also comparable implant alignment and cement mantle quality were demonstrated by obese and nonobese patients.

The anatomy of the femur may have a particular role in stem malalignment and quality of the cement mantle [20,24,31]. The real axis of the femoral medullary canal passes from the piriformis fossa. As the midpoint of the resected femoral neck usually lies anterior to the medullary axis, this may give rise to a more proximally positioned stem to the anterior cortex with the tip sloping posteriorly [9]. A lower neck osteotomy and significant cancellous bone removal from the posterior greater trochanteric region usually permit a more posterior entry point for the stem and better alignment [9,20]. In our study, no lower neck osteotomy or removal of the cancellous bone was routinely performed. The adequate cement mantle results may be attributed to the angulated insertion of the stem, the design of the stem, and routine use of a distal centralizer. Although the centralizer may optimize the distal stem tip to cortex contact and the damage in zone 12 [20,24], this cannot effectively eliminate the risk of thin cement mantles in zones 8 and 9 [20,24]. MacPherson et al. [20] demonstrated that the use of a distal centralizer was related to anterior thin cement mantles in 25% of the patients. In our study, the thinner cement mantles were reported in zones 1 and 3. Unfortunately, zones in the lateral radiographs were not evaluated.

In most studies using a different type of implants and approaches, Barrack Type B cementation was the most prevalent [34]. Using the C-stem (DePuy Synthes, Warsaw, Indiana) and posterior approach, Schuroff et al. [10] reported 5.8% type A, 53,5% type B, 31.4% type C, and 9.3% type D quality of cement mantle in 86 hips according to the Barrack classification. Ek and Choong [35] using the same stem reported 46% type B, 45.7% type A, and 8% type C cement mantles. The same authors demonstrated 56.6% type B, 36.5% type A, and 7% type D using the Exeter stem [34]. In our study, more than 90% of the mantles were of types A and B, highlighting the adequacy of the DAA in femoral cementation.

There are some limitations to the study. First, we only used plain radiographs; it is uncertain whether the use of computerized tomography will give additional information. The study was retrospective and solely investigated the DAA without comparison to a control group using another technique. However, a senior surgeon performed all the procedures reducing effect of DAA experience on results. Blinded radiology assessments reduced bias; however, we recognize the Barrack classification may have weak interobserver agreement [11]. In our study, low interobserver agreement in the grading of lateral radiographs was only seen but its effect minimized as AP radiographs were also analyzed. Our study group consisted mainly of cases with osteoarthritis. Cases treated for neck of femur fractures made up only a small part, and further investigation of such cases treated using the DAA will help determine its role.

Conclusions

This study has improved our knowledge of cemented THA using the DAA. The cement mantle quality that a surgeon should achieve is important. Our experience indicates the DAA can provide an uncompromised view to the femur that enables correct implantation of a straight femoral stem and a high-quality cement mantle even in obese patients. A high proportion of cases had grade A or B cement mantles and a stem aligned in neutral. Obesity did not affect the incidence of inadequate cement mantles or varus alignment. The mean thinnest cement mantles were recorded in the first and third Gruen zones. Long-term comparative studies are needed to explore the effect of the approach on how the quality of cementation relates to longevity of prostheses.

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Appendix

Patient	Zone 1	Zone 2	Zone 3	Zone 5	Zone 6	Zone 7	Stem		
							Radiographic length	Length (mm)	Size
1	2.34	5.7	6	3.23	4.18	0	1075.8	180	2
2	3.95	1.47	3.59	2.45	3.6	2.57	1077.6	185	3
3	2.25	2.42	3.6	1.94	4.3	3.7	1101.5	180	2
4	2.6	4.96	3.59	4.21	1.94	1.94	1221.3	205	7
5	1.99	2.35	2.24	3.33	3.37	2.17	997.6	175	1
6	0.8	2.38	3.01	3.38	4.13	3.86	1070	180	2
7	3.82	3.52	2.51	3.6	2.49	2.66	1088.4	180	2
8	1.62	3.44	2.89	5.16	3.79	1.57	1020	175	1
9	1.38	3.8	2.32	2.8	4.59	3.37	996.3	170	0
10	2.17	5.25	3.2	23	3.69	3.05	1120	180	2
11	3.8	3.24	2.61	4.33	2.47	3.00	1054	180	2
12	3.01	3.12	3.04	3.25	2.71	2.04	1254	200	6
13	2.66	3.8	4.27	4.11	3.73	4.75	1168	185	3
14	2.98	3.82	3.87	3.04	3.52	3.21	1123	185	3
15	1.65	4.93	3.14	1.57	3.34	2.34	1105	185	3
16	2.47	2.42	2.87	3.69	4.29	3.2	1090.7	180	2
17	2.39	3.18	0.98	1.61	2.28	5.22	1195	195	5
18	4.82	2.81	2.7	2.42	2.54	2.66	1031	175	1
19	3.48	3.13	3.58	2.36	3.25	2.44	1074	180	2
20	3.05	2.9	1.95	2.24	2.77	2.52	1089	180	2
21	3.27	1.97	3.06	2.79	1.9	3.13	1145	185	3
22	2.62	3.0	19.0	3.09	4.66	6	1073	175	1
23	3.15	2.66	2.58	4.09	4.46	1.27	1098	175	1
24	2.36	2.57	2.94	5.7	4.83	2.47	1074	175	1
25	2.9	3.59	2.42	2.86	3.03	3.03	1096	185	3
26	3.35	2.71	3.52	3.13	3.42	2.71	1043	175	1
27	4.87	2.8	1.96	2.47	2.91	3.56	1112	180	2
28	2.47	3.19	3.24	1.86	2.22	1.87	995	170	0
29	4.95	3.0	3.17	5.28	3.74	3.23	1090	180	2
30	1.35	1.95	1.89	4.0	3.3	2.68	1062	185	3
31	4.22	2.81	2.74	3.75	3.08	4.07	1245	195	5
32	3.03	4.62	3.18	3.58	2.98	2.39	1160	185	3
33	3.1	3.02	4.19	2.98	3.07	4.45	1161	195	5
34	2.77	2.75	2.71	3.1	4.15	4.14	1108	180	2
35	5.9	3.18	2.52	3.86	5.22	4.88	1038	175	1
36	3.16	2.33	2.33	3.08	3.5	2.16	1085	175	1
37	3.25	3.22	2.57	3.42	2.57	2.43	1079	175	1
38	2.77	3.48	1.82	2.29	2.74	2.69	1127	185	3
39	1.98	1.76	2.51	2.08	2.27	1.5	1123	180	2
40	3.07	1.63	2.21	2.76	3.92	2.73	996	170	0
41	1.63	3.71	2.17	2.34	3.54	1.95	1047	175	1
42	3.59	4.03	2.7	1.86	3.02	2.55	1100	185	3
43	4.62	3.75	2.57	1.5	0.85	1.62	1050	180	2
44	3.4	4.29	2.49	1.2	1.71	2.3	1048	180	2
45	2.55	3.04	3.16	2.68	2.75	3.13	1086	180	2
46	3.39	3.88	3.68	2.85	2.26	2.7	1066	180	2
47	3.21	3.57	1.66	1.66	1.16	2.83	1140	195	5
48	3.5	2.65	2.29	3.34	3.5	5.25	1131	180	2
49	2.73	1.77	2.23	2.3	2.39	2.9	1024	175	1
50	1.45	5.6	2.4	4.0	1.76	3.84	1092	175	1
51	2.81	3.51	3.35	3.43	3.83	2.07	1095	175	1
52	2.91	2.1	2.75	3.11	3.77	3.41	1142	185	3
53	2.58	2.38	3.4	2.39	3.74	2.38	1117	190	4
54	4.14	3.5	3.66	4.3	2.64	2.66	1130	180	2
55	1.17	1.84	1.64	2.69	2.68	3.19	1130	190	4
56	1.56	2.55	2.55	3.24	3.75	1.7	1055	180	2
57	2.73	2.5	2.76	2.32	2.14	1.78	1062	190	4
58	2.94	2.07	2.07	1.98	3.46	2.25	1039	180	2
59	4.64	3.43	4.29	3.26	1.89	1.89	989	170	0
60	3.41	4.47	4.6	3.49	3.83	2.80	1070	180	2
61	1.90	0.1	3.47	1.13	5.9	5.95	1066	180	2
62	2.39	3.03	2.69	3.16	2.79	2.87	1060	175	1
63	2.90	3.81	4.33	6.77	5.26	3.79	1091	180	2
64	2.01	2.44	2.22	0	21.3	3.56	1164	195	5
65	0	2.13	2.54	2.86	2.52	4.54	1113	180	2
66	3.32	4.02	3.12	2.72	3.04	3.44	1095	185	3
67	2.32	3.3	3.67	2.15	3.65	2.5	1107	185	3
68	2.38	1.96	2.2	1.82	2.65	2.23	1063	180	2
69	2.39	2.61	2.75	2.73	3.59	2.22	1082	185	3

(continued on next page)

(*continued*)

Patient	Zone 1	Zone 2	Zone 3	Zone 5	Zone 6	Zone 7	Stem		
							Radiographic length	Length (mm)	Size
70	2.76	2.2	2.3	3.04	2.51	2.1	1086	180	2
71	2.27	2.09	1.56	2.81	1.97	1.88	1098	185	3
72	3.49	2.47	3.25	5.03	4.91	3.22	1160	185	3
73	3.71	2.74	3.19	4.39	3.47	4.92	1165	185	3
74	3.01	3.56	1.54	3.66	2.81	3.48	1086	180	2
75	2.08	5.3	4.97	4.8	2.91	3.03	1146	190	4
76	2.87	3.51	4.78	3.76	2.03	2.11	1053	180	2
77	2.48	2.76	2.69	4.19	3.3	2.31	1056	180	2
78	3.01	3.19	1.51	4.62	4.87	4.54	1070	180	2
79	3.74	1.91	2.13	4.71	2.78	3.15	1076	175	1
80	2.19	2.19	1.41	2.67	2.85	3.92	1114	175	1
81	2.53	23	3.88	1.62	3.54	1.75	1066	180	2
82	2.18	4.03	2.01	3.52	2.68	2.35	1071	180	2
83	1.56	3.39	2.54	4.92	3.22	3.39	1060	180	2
84	2.26	2.12	2.4	2.57	2.93	5.31	991	170	0
85	2.34	3.3	4.02	3.43	3.85	2.68	1163	195	5
86	2.22	3.64	1.82	1.49	1.82	2.82	1085	180	2
87	5.54	6.19	2.44	4.23	3.09	3.58	1074	175	1
88	2.31	3.46	2.47	1.48	2.47	2.64	1121	185	3
89	4.44	3.78	2.79	4.44	3.62	4.61	1093	180	2
90	2.57	1.54	2.23	2.74	2.91	1.88	1019	175	1
91	2.64	3.63	2.03	2.9	3.7	2.52	1100	185	3
92	2.32	3.45	0.7	3.27	2.58	2.58	985	170	0
93	3.53	3.34	3.71	3.34	3.34	4.09	968	180	2
94	3.88	2.77	3.69	2.03	3.66	2.58	973	180	2
95	4.76	4.08	2.21	4.76	2.72	2.89	1116	190	4
96	3.00	2.37	2.69	2.85	3.32	2.69	1168	185	3
97	2.72	1.92	2.08	2.88	3.2	4.17	1122	180	2
98	2.88	2.63	2.3	2.3	3.62	4.12	1092	180	2
99	1.65	4.62	3.79	2.47	3.46	3.13	1181	195	5
100	2.15	3.31	3.15	0.82	0.82	3.15	1175	195	5
101	2.93	3.28	2.59	2.59	4.31	4.31	1013	175	1
102	3.23	2.8	1.65	2.47	3.3	1.81	1060	175	1
103	2.87	3.04	2.36	3.53	3.38	4.73	1124	190	4
104	2.14	2.14	3.13	2.3	2.14	2.47	1123	185	3
105	2.76	2.43	2.6	2.6	3.42	3.09	1076	175	1
106	3.26	3.09	2.57	2.4	2.91	2.91	1019	175	1
107	2.39	2.22	3.25	1.36	2.9	2.9	1023	175	1
108	3.4	1.36	2.21	0.85	2.02	3.31	1029	175	1
109	2.57	3.33	2.18	3	3.88	4.58	1020	180	2
110	2.86	1.85	1.85	1.81	3.53	4.04	1069	180	2
111	3.93	2.78	1.96	1.96	2.29	3.6	1158	190	4
112	1.58	3.88	2.47	3.35	4.58	2.64	1020	180	2
113	3.08	2.05	3.77	1.37	3.42	2.39	1021	175	1
114	1.28	3.04	2.24	1.76	3.36	2.08	1093	175	1
115	3.41	1.87	1.87	3.24	2.39	5.8	1112	190	4
116	3.2	2.77	2.11	3.42	3.74	5.37	1135	185	3