MENTORS IN ORTHOPEDICS

DOES SURGICAL APPROACH INFLUENCE CANAL FILL OF THE FEMORAL COMPONENT FOR THA?

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SUMMARY

Background: Cementless femoral components in hip arthroplasty require optimal primary stability and long-term osseointegration. Inadequate implant sizing may lead to early loosening, subsidence, or periprosthetic fractures. While morphological variability of the proximal femur is a known cause of undersizing, there is ongoing debate regarding whether specific surgical approaches, particularly the direct anterior approach, increase the risk of suboptimal femoral canal fill.

Objective: This study aimed to evaluate the correlation between four different surgical approaches and the canal fill ratio (CFR) of cementless femoral components, while accounting for host femoral morphology.

Key Points: A retrospective radiographic analysis was performed on 183 patients who underwent primary hip arthroplasty using a single anatomical stem design. Patients were categorized by surgical approach: Heuter (n=40), Rottinger (n=53), modified Hardinge (n=50), and Moore (n=40). Femoral morphology was classified using the Canal Flare Index (CFI) and the Dorr classification (Canal Calcar Ratio). Statistical analysis demonstrated no significant difference in CFR across the four surgical approaches at any of the four measured levels ($p > 0.05$). Although the Rottinger approach showed slightly higher proximal fill in "normal" shaped canals ($p < 0.0091$), surgical approach was not a primary determinant of undersizing. Distal and proximal fill ratios were significantly influenced by preoperative femoral morphology (CFI and CCR) rather than the surgical portal used.

Conclusion: Surgical approach does not significantly influence the canal fill of anatomical cementless femoral components. The risk of implant undersizing appears related to femoral morphology and implant design rather than the choice of surgical exposure.

KEYWORDS

Arthroplasty, Replacement, Hip; Femur; Prosthesis Design; Radiography; Bone Cements

INTRODUCTION

Modern hip arthroplasty offers excellent functional outcomes and long-term survival. [1],[2] Cementless implants are becoming increasingly popular due to their good primary stability and excellent long-term osseointegration. [3] Choosing the right size of the cementless femoral component is crucial. Too small and it can lead to early loosening, fractures due to femoral stem subsidence and/or failed osseointegration. [4],[5],[6],[7] On the other hand, a well-sized femoral component will correctly distribute stresses over the proximal femur [10] and ensure good biological fixation. [8],[9] Anatomically, the shape of the proximal femur can vary greatly. This morphological variability is a major cause of implant undersizing and early revision. [11],[12],[13] The choice of surgical approach also appears to affect femoral component canal fill. Some authors believe the anterior approach paves the way for femoral component undersizing. [14] Given the fracture risk posed by an anterior or anterolateral portal and the difficulties should osteosynthesis be required, many surgeons find it easier to employ successive femoral rasps when using these approaches. Overall, undersizing the shaft can be made difficult by the bone structure, femoral offset, medullary canal diameter and the surgical approach.

The primary aim of this study was to investigate any correlation between surgical approach and the canal fill of cementless femoral components. We used the hypothesis that surgical approach does not influence femoral component canal fill for hip arthroplasty. Our analysis of femoral canal fill included a morphological analysis of the host femurs.

MATERIALS AND METHOD

1. Study Population

This retrospective study was conducted at Martinique Teaching Hospital and comprised a radiographic analysis of 183 patients following primary arthroplasty (total or hemi) of the hip between January 2016 and December 2018.

Inclusion criteria: (1) Adults (>18 years) who had undergone a (2) primary hip arthroplasty (3) with a Hip'n go cementless femoral implant (FH Ortho) and who had a (4) preoperative and postoperative frontal weight-bearing x-ray.

The patients were divided into four groups based on surgical approach. Group 1 patients had undergone the Heuter approach with no orthopaedic table (n=40); Group 2 patients had undergone the Rottinger approach (n=53); Group 3 was for the modified Hardinge approach (n=50); and the Moore posterolateral approach had been used for Group 4 patients (n=40). All patients had been operated by senior surgeons, each performing the surgery using his or her preferred approach.

2. Endpoints

Implant size was determined using the canal fill ratio (CFR) [18] measured at four different points on the weight-bearing postoperative images: the lesser trochanter, 2cm above and below the lesser trochanter, and 7cm below the lesser trochanter (Figs. 1 & 2).

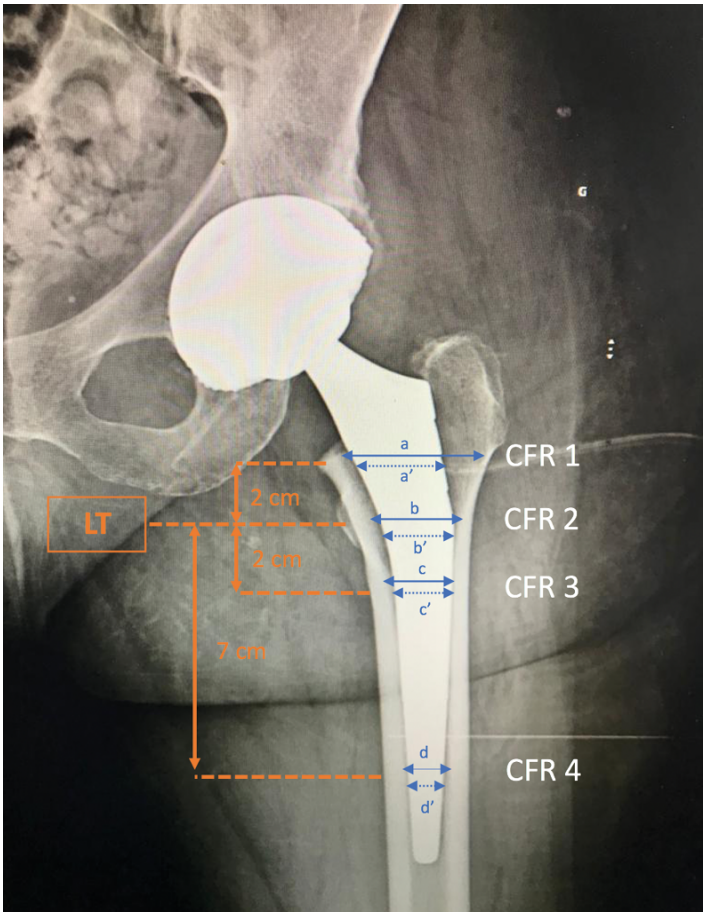

Figure 1: Implant size was measured on the x-rays using the canal fill ratio (CFR) at four different points on the postoperative x-ray: the lesser trochanter, 2cm above and below the lesser trochanter, and 7cm below the lesser trochanter.

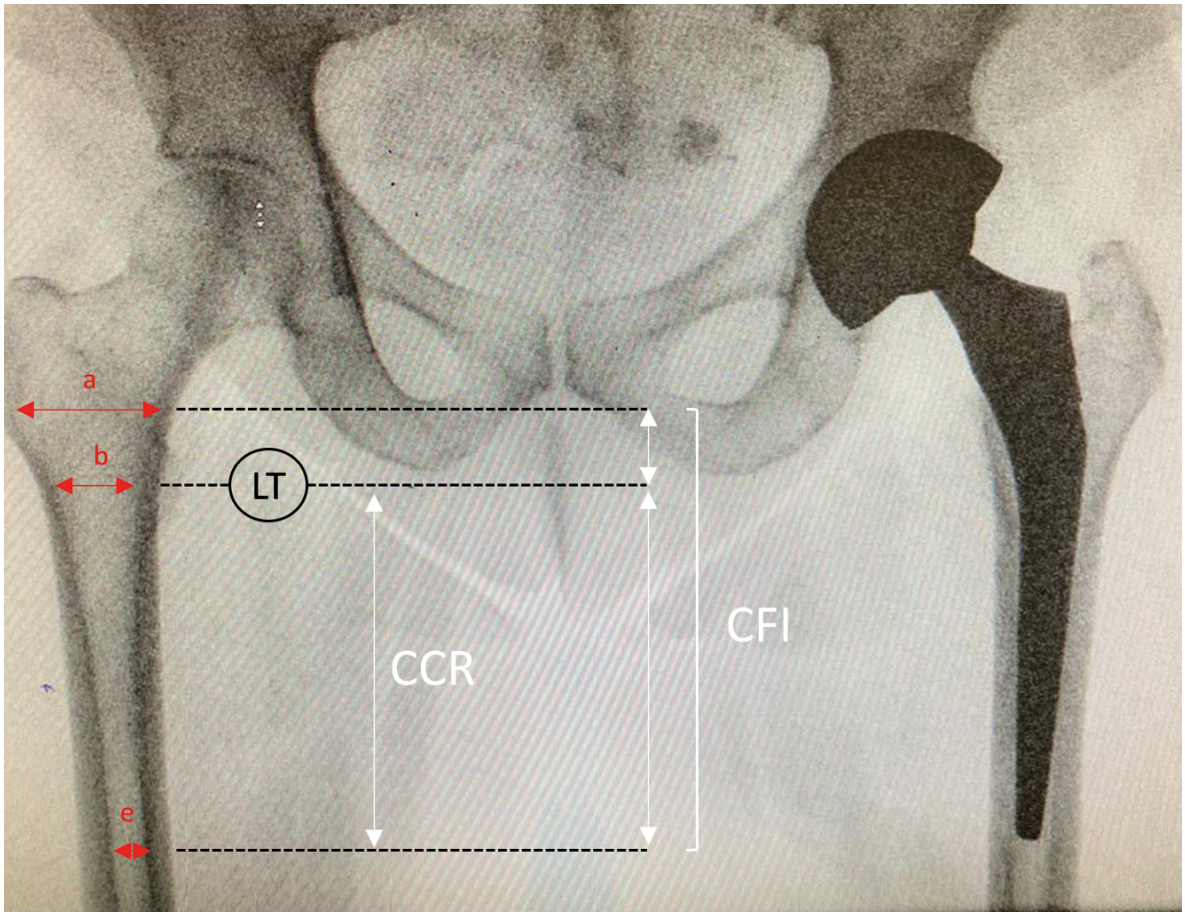

Figure 2: Canal flare index (CFI) was defined as the width of the medullary canal 2cm above the lesser trochanter, divided by the width of the canal 10cm below the lesser trochanter. Canal calcar ratio (CCR) was defined as the width of the medullary canal 10 cm below the lesser trochanter divided by the width of the canal at the lesser trochanter.

Femur shape was determined using the canal flare index (CFI) as measured on the preoperative x-rays.[15] CFI was defined as the width of the medullary canal 2cm above the lesser trochanter, divided by the width of the canal 10cm below the lesser trochanter. Using the criteria established by Noble et al., [15] a CFI < 3.0 was classed as a stovepipe canal shape, a CFI between 3.0 and 4.7 was classed as normal canal shape, and a CFI > 4.7 was classed as a champagne-fluted canal shape (Fig. 3). The canal calcar ratio (CCR) [16] was also measured to establish femoral shape according the Dorr classification. [17] CCR was defined as the width of the medullary canal 10cm below the lesser trochanter, divided by the width of the canal at the lesser trochanter. A CCR < 50% was classified as Dorr type A, a CCR between 50 and 75% was classified as Dorr type B, and a CCR > 75% was classified as Dorr type C. Radiographic analysis was performed independently by two senior surgeons who knew neither the patient identity nor the surgical approach used.

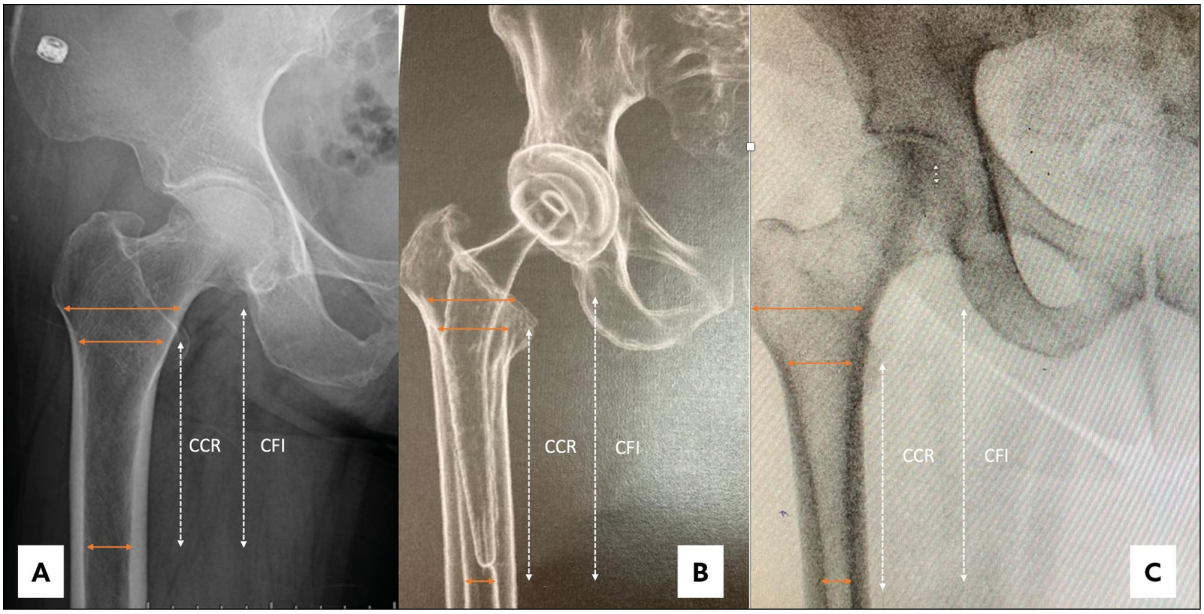

Figure 3: Radiographic measurements of CFI: (a) < 3.0 (stovepipe canal); (b) between 3.0 and 4.7 (normal canal); (c) > 4.7 (champagne-fluted canal).

3. Statistical analysis

Data were collected in an Excel spreadsheet (Microsoft, Richmond, WA) and analysed using JMP 10.0 (SAS Inc., Cary, NC) based on a protocol validated by an Institutional Review Board (IRB) overseen by our institution's research department (IRB). A Shapiro-Wilk test was performed to test the normal distribution of quantitative variables. A post-hoc test was used to compare the mean of multiple quantitative variables with normal distribution. The significance threshold was $p<0.05$ for all tests. The inter-rater correlation of the x-ray measurements was determined using the Kappa correlation coefficient, and inter-rater agreement was expressed as a percent.

RESULTS

A total of 183 patients were included; 110 were women and 73 were men. The average age was 74.4 ± 13.2 years. The series comprised 108 total hip arthroplasties and 75 hemiarthroplasties ($p<0.0001$), with a similar distribution between different surgical approaches (p=NS) . Full patient characteristics are given in Table 1.

	Hueter	Rottinger	Hardinge	Posterior	p-value
N	40	53	50	40	NS
Age	73,0 (±11,9)	78,2 (±14,9)	73,16 (±14,8)	72,2 (±12,3)	NS
Gender (M/F)	19/21	20/33	18/32	16/24	NS
Side (R/L)	18/22	24/29	20/30	24/16	NS
HA/THA	17/23	35/18	12/38	11/29	< 0,0001
CFI					
Stovepipe canal shape	22	39	30	26	NS
Normal canal shape	15	12	18	13	
Champagne-fluted canal shape	3	2	2	1	
Dorr Classification (CCR)					
Dorr A	23	15	21	20	NS
Dorr B	14	34	26	17	
Dorr C	3	4	3	3	

Table 1: Patient characteristics (HA: hemiarthroplasty, THA: total hip arthroplasty, CFI: canal flare index, CCR: canal calcar ratio).

Canal fill and approach

No significant difference was found between surgical approach and CFR measured at four different points (CFR 1, 2, 3, and 4) on the weight-bearing postoperative x-rays. Canal fill was therefore not dependent on surgical approach (Table 2).

	Hardinge	Hueter	Posterior	Rottinger	p
N	50	40	40	53	
CFR> 2cm LT	0,65 ± 0,11	0,62 ± 0,09	0,67 ± 0,17	0,63 ± 0,11	**NS**
CFR LT	0,70 ± 0,09	0,72 ± 0,09	0,72 ± 0,08	0,72 ± 0,12	**NS**
CFR < 2 cm LT	0,73 ± 0,10	0,74 ± 0,09	0,74 ± 0,11	0,77 ± 0,13	**NS**
CFR < 7 cm LT	0,74 ± 0,11	0,80 ± 0,11	0,77 ± 0,14	0,79 ± 0,10	**NS**
Canal calcar ratio (CCR)	0,53 ± 0,11	0,50 ± 0,10	0,53 ± 0,12	0,54 ± 0,13	NS

Table 2: CFR at four different points and surgical approach.

Canal fill, surgical approach and femoral shape

When femoral shape was assessed using CFI, surgical approach resulted in no significant difference in canal fill at either of the four measurement points for either stovepipe canals or champagne-fluted canals.

In the normal canal shape group, there was a significant difference at the lesser trochanter. After the multiple student test (posthoc analysis), canal fill was greater at the lesser trochanter for the Rottinger group than for the Heuter, Hardinge, and Moore groups. ($p<0.0091$). When comparing the shape of the femur according to the Dorr

Classification and CCR measurements, there was no significant difference in canal fill between the surgical approaches.

Canal fill and host femur shape (irrespective of surgical approach)

A comparison of CFI and CFR found, as to be expected, that stovepipe femurs had low distal canal fill, whereas champagne-flute femurs had high distal canal fill (Table 3). Likewise, looking at CCR, Dorr type A host femurs had greater distal fill than proximal fill. The opposite was found for Dorr type C femurs, whose proximal fill was greater than their distal fill (Table 4).

	Stovepipe canal shape (1)	Normal canal shape (2)	Champagne-fluted canal shape (3)	p-value	Post-hoc test
CFR >2cm LT	0,68 ± 0,13	0,58 ± 0,06	0,57 ± 0,04	<0,0001	1 > 2 et 3
CFR LT	0,72 ± 0,11	0,71 ± 0,09	0,64 ± 0,10	0,13	NS
CFR < 2cm LT	0,73 ± 0,12	0,77 ± 0,10	0,70 ± 0,10	0,09	NS
CFR < 7 cm LT	0,74 ± 0,11	0,84 ± 0,10	0,83 ± 0,13	<0,0001	1 < 2 et 3

Table 3: Canal fill by CFI.

	Dorr A (1)	Dorr B (2)	Dorr C (3)	p-value	Post-hoc test
CFR> 2cm LT	0,61 ± 0,12	0,66 ± 0,11	0,71 ± 0,14	0,0026	1 < 2 et 3
CFR LT	0,68 ± 0,09	0,74 ± 0,09	0,80 ± 0,14	<0,0001	1 < 2 < 3
CFR < 2cm LT	0,77 ± 0,12	0,74 ± 0,10	0,72 ± 0,13	0,15	NS
CFR < 7 cm LT	0,84 ± 0,10	0,75 ± 0,10	0,63 ±0,12	<0,0001	1 > 2 > 3

Table 4: Canal fill by CCR.

For all radiographic measurements, inter-rater correlation was 98% with a Kappa correlation coefficient of 0.96 [0.88–1].

DISCUSSION

This study showed that surgical approach in hip arthroplasty does not influence canal fill and is therefore not a factor in undersizing of the femoral component. An undersized femoral implant is a risk factor for early loosening. As shown by Fottner et al. [19], undersizing of the stem leads to increased micromovements and stress shielding. Angerame et al. showed that revisions for early femoral implant loosening are more common with the anterior approach and that loosening occurs most frequently in Dorr type A femurs when an anterior portal is used. [20] Our study found that, regardless of Dorr femur shape, surgical approach is not a factor of implant undersizing. This early loosening with Dorr type A femurs when an anterior approach is used is probably due to poor metaphyseal fill. Indeed, as shown by Park et al., the survival rate of uncemented stems is lower with Dorr type A femurs than for type B. [21] The primary determining factor for femoral component survival would

therefore appear to be metaphyseal canal fill, which is largely dependent on implant design. In order to ensure our comparison of canal fill was feasible and reliable we used a single femoral implant design (anatomical stemmed). This was not only an essential prerequisite, but also a limitation of our study. Janssen et al. showed in their study that early loosening of so-called straight femoral implants (with shoulder) is more common with an anterior or anterolateral approach than with a posterior approach, but the study showed no difference with anatomical implants. [22] This could be explained by the fact that femoral exposure is more complex with an anterior or anterolateral portal, hampering metaphyseal preparation which could lead to malposition and/or undersizing of the straight implant.; however, this was not confirmed in our study with an anatomical implant.

Another limitation of our study derives from the fact that it involved a retrospective analysis of radiographic measurements, with no patient follow-up and therefore no assessment of osseointegration or loosening. However some authors such as Graw et al. have found that minimally-invasive procedures are a risk factor for early failure due to poor osseointegration and early loosening. [23]

Furthermore, surgical approach influences the occurrence of proximal periprosthetic osteolysis due to varying degrees of soft tissue damage during the operation, affecting stress distribution around the proximal femur. [24], [25]

The aetiology of early loosening following anterior and minimally-invasive procedures is unclear but is often attributed to the difficulty of exposure which leads to undersizing or malpositioning the implant. However, our work confirms that, despite some difficulties in exposing the medullary shaft as described by some authors, the anterior approach is not a risk factor for undersizing an anatomical femoral implant.

CONCLUSION

Surgical approach in hip arthroplasty does not influence canal fill and is therefore not a factor in undersizing the femoral component.

Although femoral canal fill is closely linked to the morphology of the host femur, we found no correlation between surgical approach, femoral shape and canal fill.

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