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Original Research

Does Lack of Initial Collar-Calcar Contact Influence Performance of Collared Cementless Femoral Stems?

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ABSTRACT

Background: Initial stability of cementless stems is important to minimize the risk of subsidence, pain, and periprosthetic fracture after total hip arthroplasty (THA). Collared stems improve initial component stability when contacting the femoral calcar. Direct contact is not always achieved, and collared stem performance has not been studied in this context. We hypothesized that collared stems achieving direct contact would demonstrate reduced subsidence.

Methods: A single-surgeon retrospective study of 482 consecutive primary THAs implanted between February 2020 and May 2023 using collared cementless stems was performed. The 2 cohorts included stems with initial collar-calcar contact vs stems without. Subsidence was evaluated by comparing intraoperative fluoroscopy to postoperative 8-week radiographs. Binary logistic regression identified independent risk factors for subsidence. Chi-square tests were used for categorical variables and *t*-tests for continuous variables.

Results: Of stems, 63.9% achieved initial collar-calcar contact, while 36.1% did not. The rate (1.3% vs 19.0%; $P < .001$) and magnitude (0.02 mm, range 0-3 mm vs 0.35 mm, range 0-3 mm; $P < .001$) of subsidence were significantly higher among stems without initial contact. Stems without initial collar-calcar contact ($P < .001$) and male gender ($P = .007$) were independent risk factors for subsidence. Two patients with initial contact had nondisplaced calcar cracks and <3 mm of subsidence at 4 weeks, which healed with protected weight-bearing. Stem survivorship was 100% in both groups, with all achieving osteointegration and none needing revision.

Conclusions: Excellent performance of collared cementless stems was observed at 8 weeks after primary THA. Initial collar-calcar contact lowered the risk and magnitude of minor subsidence but did not affect survivorship or fracture risk.

Level of Evidence: Level III.

Introduction

Total hip arthroplasty (THA) is among the most successful orthopaedic procedures and is projected to continue to see a significant increase in utilization [1-3]. Previous data suggest that the choice of implant fixation, either cemented or cementless, should be determined on case-to-case basis given patient age, diagnosis, and bone quality to give the best implant survivorship and stability, as there has been no data that shows one fixation method that is objectively and universally superior [4-6]. With such a considerable and increasing volume of THAs being performed each year, it is important to continue evolving this procedure to improve and optimize clinical outcomes and patient experience.

Subsidence, defined as distal migration of the femoral stem within the canal, is a relatively common occurrence, with cementless stems usually being at a significantly greater risk than cemented stems [7-9], although some types of cemented stem designs such as taper-slip stems are designed to function through mildly controlled stem subsidence [10]. Osteointegration of the

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cementless implant occurs during the postoperative 4-to-12-week period and continues for up to 3 years [11]. However, Selvaratnam et al. showed that femoral stem subsidence is confined mostly to the first 6 postoperative weeks, which stabilized after this period, and Strom et al. showed that the majority of stem subsidence occurs within the first 2 months, demonstrating that stem subsidence is very unlikely to occur after this initial 2-month postoperative period [12,13]. Subsidence can be asymptomatic; however, subsidence can also negatively affect rehabilitation efforts or lead to postoperative complications such as loosening and periprosthetic fractures (PPFx), both of which are risk factors for revision THA [14-16]. One prior study demonstrated that at 2 years postoperatively, the probability for revision is 50% and 95% with a stem subsidence of >1.2 mm and >2.6 mm, respectively [14].

Initial stability of the cementless stem relies on the mechanical “press-fit” of the prosthesis within the femur, and implanting a mechanically stable hip prosthesis limits the risk of subsidence, fracture, and loosening and improves the likelihood of successful osteointegration. One design feature that may improve initial stem stability is a collar. While some studies have shown no significant differences in achieving successful femoral fixation using a collared vs collarless stem [17], the purported benefit of using a collared stem is to provide greater initial stem stability by transferring some of the load to the calcar. Assessing stability using force on cadaver THA, greater immediate stability was observed in collared cementless stems than collarless stems for both subsidence and fracture [18]. Not surprisingly, other studies have demonstrated that collared stems have lower subsidence rates than collarless stems at 2 weeks [19] and at 7 months [20] after THA.

Previous studies have shown that attaining contact between the prosthesis stem collar and the femoral calcar intraoperatively during THA increased stability and reduced the rate of periprosthetic fracture [21-23]. Recent research has begun to explore how collar-calcar contact may be able to reduce the rate of subsidence as well [24]. However, collar-calcar contact is not always achieved; one study reported collar-calcar contact in only 47% of patients with collared stems [25]. Achieving collar-calcar contact and methods to do so can become of greater importance during THA if research continuously displays its benefits. The current study aims to explore the implications of achieving collar-calcar contact on the rate of subsidence and stem performance in primary THA patients with a collared cementless stem. We hypothesized that collared stems achieving direct contact would demonstrate a reduced subsidence rate at the 8-week postoperative mark.

Material and methods

After obtaining approval from our institutional review board, a single-surgeon retrospective cohort study of all primary THAs implanted between February 2020 and May 2023 using collared cementless stems was performed. All THAs were performed via direct anterior approach using a standard operating room table. Patients included in the study received one of 2 collared cementless femoral stems (Avenir Complete, Zimmer-Biomet, Warsaw, IN; Actis, DePuy, Warsaw, IN). Patients with complex primary THAs, cemented or collarless stems, and those who were lost to follow-up before 8 weeks were excluded.

Demographic variables including age, gender, and body mass index (BMI) were collected from our research database. Intraoperative fluoroscopy was taken in multiple planes, and the best image was compared to 8-week postoperative radiographs to identify the presence or absence of initial collar-calcar contact, incidence and depth of subsidence, and presence of any calcar cracks or PPFx. The femoral rotation during intraoperative fluoroscopy was determined by the profile of greater and lesser trochanters and was taken in multiple planes. The image used in the comparison was chosen based on the best plane approximation of the postoperative radiographs. The 8-week postoperative period was chosen for radiographic evaluation based on previous data showing femoral stem subsidence occurring mostly in the first 6 to 8 postoperative weeks, stabilizing after this period [12,13], and subsidence occurring between the postoperative 4 to 7 weeks on average [7,12]. Collar-calcar contact was defined as any direct contact between the undersurface of the collar and the medial femoral cortex on the final anteroposterior fluoroscopy view. Stems that did not achieve collar-calcar contact either had contact with the undersurface of the collar with cancellous bone inside (lateral to) the calcar or were implanted in a position where the collar was left above the neck cut and not contacting any bone on the medial femur. Subsidence rates were measured on radiographs to the nearest 0.5 mm after image calibration with a marker ball. The population was divided into 2 cohorts for statistical analysis: stems that were contacting vs those that were not contacting the calcar at implantation.

Statistical analyses

SPSS software version 28.0.0.1.0 (Chicago, IL) was used for statistical analyses. Patient demographics, characteristics, and initial collar contact were examined to determine correlation between initial collar contact and incidence of subsidence. Chi-square tests were used to examine for differences between groups for categorical variables such as gender, incidence of subsidence, and incidence of PPFx, and *t*-tests for continuous variables such as age, BMI, and subsidence depth. Binary logistic regression was used to identify independent risk factors for subsidence. Risk factors measured included gender, age, BMI, and initial collar-calcar contact. A *P*-value of < .05 was considered significant.

Results

A total of 650 patients who underwent primary THA during the study period were reviewed, of whom 482 hips received collared cementless stems and met inclusion criteria to be evaluated in the current study; 17 THAs were lost prior to an 8-week follow-up radiograph. Of those, 308 hips (63.9%) were identified as having stems with initial collar-calcar contact, while 174 hips (36.1%) had stems implanted without initial collar-calcar contact (Table 1).

The rate of subsidence was significantly greater when there was an absence of initial collar-calcar contact. 19.0% of stems without initial contact demonstrated measurable subsidence (Fig. 1), while only 1.3% of stems with initial collar-calcar contact demonstrated any measurable subsidence ($P < .001$; Table 2). While no stem in either group subsided more than 3.0 mm, the magnitude of subsidence was also significantly greater when there was no initial collar-calcar contact, with a mean subsidence depth of 0.35 ± 0.74 mm (range 0-3 mm) without initial calcar contact compared to only 0.02 ± 0.24 mm (range 0-3 mm) with initial calcar contact ($P < .001$; Table 2).

Table 1
Patient demographics by cohort.

Demographics	*N*	Contact	No contact	*P*-value
N (%)	482	308 (63.9)	174 (36.1)	—
Gender, n (%)				
Male	251 (52.1)	136 (44.2)	115 (66.1)	<.001
Female	231 (47.9)	172 (55.8)	59 (33.9)	
Age (y)	—	63.2	62.1	.242
BMI (kg/m^2)	—	28.7	29.2	.357

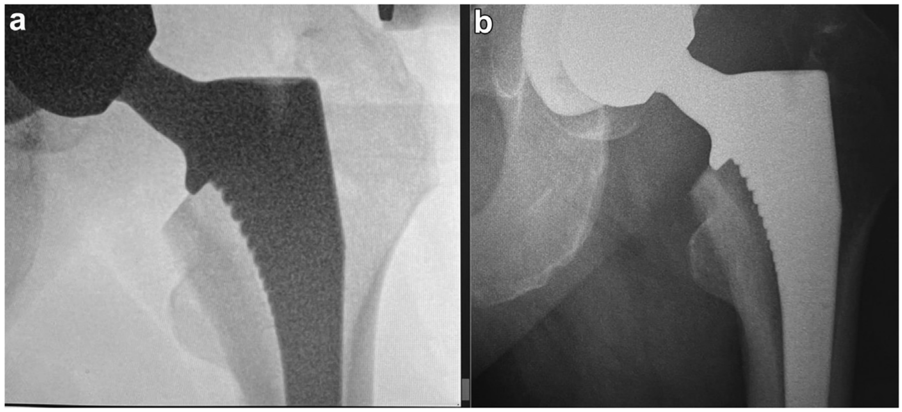

Figure 1. (a) Primary THA patient without collar-calcar contact shown on intraoperative fluoroscopy vs (b) 3 mm stem subsidence shown on an 8-week postoperative radiograph. Measurable subsidence occurred in 19.0% of patients without initial collar-calcar contact.

Although there were no differences in age and BMI between the groups defined as stems with initial collar-calcar contact and stems without initial collar-calcar contact, there were significantly more males in the group of stems without initial collar-calcar contact (Table 1). Therefore, a binary logistic regression was completed, which identified being male as an independent risk factor for subsidence ($P = .007$; 95% confidence interval, 1.41-9.13); however, the greatest risk factor for subsidence was stems without initial collar-calcar contact ($P < .001$; 95% confidence interval, 0.023-0.19). Age and BMI were not identified as independent risk factors for subsidence (Table 3).

While none of the 482 hips (0.0%) suffered intraoperative or postoperative PPFx requiring reoperation or stem revision, 2 patients (0.4%) suffered postoperative incomplete nondisplaced calcar cracks at approximately 4 weeks postoperatively. Both patients were males who had initial collar-calcar contact and were found to have incomplete nondisplaced calcar cracks with 2.5 to 3 mm of subsidence at their first postoperative radiograph (Fig. 2). While there is a possibility these may have been unrecognized intraoperative calcar cracks, there was no evidence based on close examination of the bone during surgery or on careful retrospective inspection of the intraoperative fluoroscopic or postoperative radiographic anteroposterior and lateral views to confirm this. In addition, both patients were able to walk without significant pain for at least the first 2 weeks after surgery before pain developed. Both incomplete calcar cracks healed uneventfully without further subsidence with protective weight bearing. Despite both of these patients being in the same cohort, there was no difference in the rate of calcar fractures between groups (0.6% vs 0.0%; $P = .287$) (Table 4). All 482 stems had radiographic signs of successful early osteointegration at 8 weeks postoperatively, with none demonstrating any signs of clinical failure or requiring early revision (0.0%; $P = 1.0$) (Table 4).

Discussion

As surgical practices evolve, it is important to continually assess what surgeons can do to produce the best clinical outcomes. With pain, fracture, and revision being known risks of stem subsidence [14-16], additional considerations should be made to reduce the rate of subsidence, even when the incidence and magnitude of subsidence with modern implants are quite small. Specifically, Kärrholm et al. reported the probability for revision as 50% in stems with 1.2 to 2.6 mm of subsidence vs a significantly higher revision rate of 95% in stems with greater than 2.6 mm of subsidence [14]. Additionally, Kärrholm et al. found that revision femoral stems with greater than 0.33 mm of subsidence with a total migration of more than 0.85 mm were predictive of an increased risk of revision [14], although it is not clear how this relates to primary stems. While minimal amounts of subsidence less than 1 mm may not be clinically relevant in primary femoral stems, the magnitude of subsidence is likely an important variable to consider, as revision rates have been shown to increase as the amount of stem subsidence increases. The current study supports the theory made by Jeon et al. in that achieving initial collar-calcar contact intraoperatively can significantly reduce the risk of stem subsidence [24]. Compared to that study, a much larger sample size was evaluated in the current study, which demonstrated that not having initial collar-calcar contact was an independent risk factor for subsidence. Additionally, not only was the rate of subsidence significantly less, but the magnitude of subsidence was also significantly less in stems with initial collar-calcar contact.

Another independent risk factor for stem subsidence found in the current study was male gender. Ries et al. also found that the mean subsidence was significantly higher in males (3.5 ± 3.2 mm) than females (2.4 ± 2.1 mm) [20]. They attributed this finding to males having a higher body weight, which was consistent with their BMI data showing males had a significantly higher BMI than females. It is important to note that Ries et al. measured a much higher magnitude of subsidence among collared femoral stems compared to the findings in the current study, likely because many of the stems in that study were collarless and subsided at a significantly higher rate than collared stems in their study [20]. Notably, the current study also found that males were significantly

Table 2
Results of chi-square and *t*-test analyses of subsidence rate and depth for stems with initial collar-calcar contact and stems without initial collar-calcar contact groups.

All patients (n = 482)	Contact (n = 308)	No contact (n = 174)	*P*-value
Subsidence, n (%)	4 (1.30)	33 (19.0)	<.001
Subsidence depth (mm)	0.02 (range 0-3 mm)	0.35 (range 0-3 mm)	<.001

Table 3
Binary logistic regression identifying independent risk factors for stem subsidence.

Binary logistic regression	Odds ratio (95% confidence interval)	*P*-value
Gender, male	1.277 (1.410-9.129)	.007
Age	0.011 (0.976-1.047)	.546
BMI	−0.020 (0.909-1.057)	.605
Contact	−2.72 (0.023-0.192)	<.001

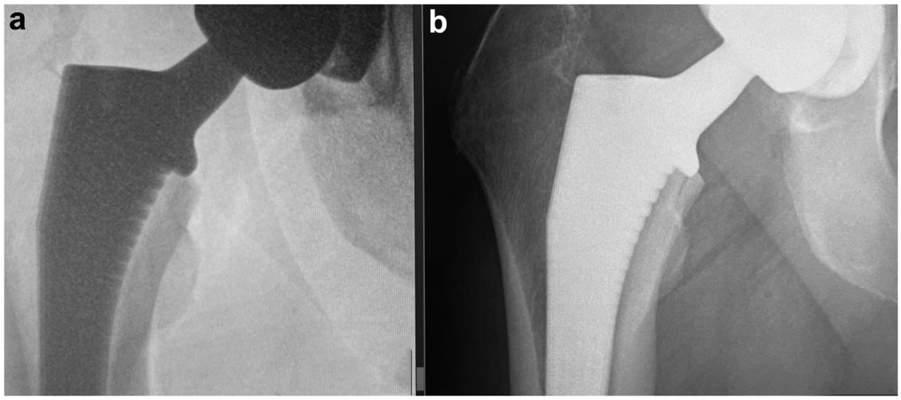

Figure 2. (a) Primary THA patient with initial collar-calcar contact shown on intraoperative fluoroscopy vs (b) 3 mm stem subsidence and a nondisplaced calcar fracture at 4 weeks postoperatively. Two patients (0.4%) had these postoperative calcar fractures, both of which healed uneventfully.

less likely to achieve initial collar-calcar contact. This finding could be explained by gender differences in native proximal femur anatomy. Femoral neck shaft angle, femoral neck version, femoral offset, and femoral canal flare index have all been shown to be significantly different between males and females. The authors suggested these differences may be useful to consider to optimize native hip anatomy restoration during hip reconstruction [26].

Patients with collared stems that achieve good collar-calcar contact have increased stability during flat-walking and stair-climbing, compared to patients with collared stems without collar-calcar contact, who have stability similar to patients with collarless stems [21]. Collar-calcar contact has also been shown to reduce the risk of periprosthetic fracture [22,23]. Having adequate collar coverage and achieving collar-calcar contact not only provide the most stability but could also reduce subsidence [24].

The design of collared stems may have an influence on some of these clinical outcomes. The optimal collar size should be proportional to the size and morphology of the prosthesis used in order to provide maximum calcar coverage [27]. However, some stem designs do not change the size and shape of the collar as the stem size changes, which can leave patients with over- or under-sized collars without adequate collar-calcar contact. Subsidence may occur in patients with undersized collars, while soft tissue impingement may occur in patients with oversized collars that present with an overhang [27,28]. Additionally, the ability to seat the collar flush with the neck cut is important, and stems that do not fully seat to this level of contact may be more likely to subside. With the 2 designs used in this study, the final stem consistently sat at the level of the broach; however, this may be a potential concern with other stems that are designed to sit up from the calcar [29]. Research such as the current study and similar future studies could help format the basis for modifying stem designs to include options that include different collar sizes.

One limitation of the study design is that the current study was conducted retrospectively, with some patients being lost to follow-up before 8 weeks. Additionally, our methodology study focused on radiographic outcomes and complications such as subsidence and fracture but did not incorporate outcome measures for pain or function, as those were not readily available for all patients. Second, radiographic data were acquired by manually measuring stem subsidence on radiographs and fluoroscopy images. While the presence of the collar adjacent to the calcar typically allows for easy radiographic identification of subsidence between images, this methodology may fail to account for subsidence as accurately as radiostereometric analysis would. Third, the implant design and shape and size of the collar were not taken into consideration when doing the analysis, and the performance of the collar may vary based on the size and shape of the collar varying across designs.

A strength of the current study is that a large cohort of patients was used to explore stem subsidence based on collar-calcar contact, a comparison not commonly studied previously [24]. There was also an approximate equal representation of gender, which strengthens our finding that being male is an independent risk factor for subsidence.

Table 4
Results of the chi-square analysis of postoperative complications.

All patients (n = 482)	Contact (n = 308)	No contact (n = 174)	*P*-value
Calcar fracture (%)	2 (0.6)	0 (0.0)	.287
Revision (%)	0 (0.0)	0 (0.0)	1.0

Conclusions

Achieving initial collar-calcar contact is associated with a reduction in the rate and magnitude of subsidence in primary THA patients with collared cementless stems. Absence of initial collar-calcar contact and male gender were both found to be independent risk factors for subsidence in cementless collared stems. It is important to keep in mind that despite the presence of radiographically measurable subsidence, the overall magnitude was relatively minor and may have little clinical relevance, as it did not lead to stem loosening or periprosthetic fracture in any patients. We observed excellent stem performance at the 8-week postoperative period, whether or not collar-calcar contact was achieved, with none needing early revision (0.0%) and no difference in complications or fracture. Future studies with multiple trained arthroplasty surgeons can further strengthen these findings to better understand how the risk of subsidence can be reduced and if collar-calcar contact is a reliable indicator of such risk.

Conflicts of interest

R. P. Shah is a paid consultant for DePuy, Link Orthopaedics, Monogram, and Zimmer; is an unpaid consultant for OnPoint; has stock options in Parvizi Surgical Innovations; and is a board/committee member of the American Association of Hip and Knee Surgeons and the US Food and Drug Administration. H. J. Cooper is a 3M speaker; is a paid consultant for DePuy, 3M, Zimmer-Biomet, Canary, and Polaris; has stock options in Polaris; receives research support in Smith & Nephew; is an editorial board member of the

Journal of Bone and Joint Surgery; and is a board/committee member of the American Academy of Orthopaedic Surgeons and the Eastern Orthopaedic Association. All other authors declare no potential conflicts of interest.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101432.

CRediT authorship contribution statement

Travis R. Weiner: Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Data curation, Conceptualization. **Catelyn A. Woelfle:** Writing – review & editing, Writing – original draft, Visualization. **Winnie Xu:** Writing – review & editing, Validation, Supervision. **Duke G. Yim:** Writing – review & editing, Validation, Conceptualization. **Roshan P. Shah:** Writing – review & editing, Validation, Supervision, Conceptualization. **H. John Cooper:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Conceptualization.

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