Comparative Analysis of Cemented vs Press-fit Fixation in Total Hip Arthroplasty

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Abstract

Research Question: In patients undergoing hip arthroplasty, does the restricted access of the Direct Anterior (DA) approach negatively impact the cementing technique compared to cemented arthroplasty with press-fit fixation, and does this cementing technique decrease the occurrence of loosening and fractures when compared to press-fit fixation utilizing the same surgical approach?

Objectives: The purpose of this study was to use a combination of the direct anterior (DA) approach and the cemented replacement technique to achieve the functional benefits of the DA approach as well as the fixation benefits of cemented replacement. The limited access to the hip of the DA approach may have a negative impact on the cement technique. Additionally, does the use of such a cementing technique minimize the proportion of patients who experience difficulties that are not caused by cement?

Methods: We conducted a retrospective analysis of 341 patients (360 hips) who underwent the DA total hip arthroplasty (THA) approach between 2016 and 2018. The total number of press-fit stems was 203, while the number of cemented stems was 157. The average age in the press-fit group was 75 years (ranging from 70 to 86), while in the cemented group it was 76 years (ranging from 52 to 94). Of the 341 patients, 239 individuals (70%) were females. The occurrence of femoral complications was compared between the two groups. The average duration of follow-up was 1.5 years (ranging from 0.1 to 4.4 years) for patients in the press-fit group, and 1.3 years (ranging from 0.0 to 3.9 years) for patients in the cemented group.

Results: The press-fit group had a greater incidence of complications related to the femur (8 vs 0; $p = 0.011$). There were a total of two stems with failure of fixation and six instances of bone fractures, all of which necessitated further examination and correction. Fractures were observed at an average of 14.5 days (ranging from 2 to 31) after the surgery, while loosening occurred at 189 and 422 days after the surgery. The femoral cementing procedure can be safely performed using the DA approach, resulting in a lower incidence of complications compared to a contemporary series that does not involve the use of cement.

Conclusion: Press-fit stems exhibited a greater incidence of early fractures and loosening. A similar rate of complication was not observed in our group of patients who received cemented stems. The process of cementing was successfully carried out using the DA approach without any complications. Femoral cementing during THA using the DA approach does not contribute to surgical intricacy or duration, exhibits fewer initial femoral complications, and represents a safer alternative for elderly patients when compared to press-fit femoral arthroplasties.

Research Question

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Introduction

THA, or total hip arthroplasty, is a highly cost-effective and consistently successful surgical procedure commonly performed to treat end stage osteoarthritis. THA offers dependable results for patients with advanced degenerative hip osteoarthritis or osteonecrosis, congenital hip disorders, and inflammatory arthritis.[1] It specifically focuses on alleviating pain, enhancing functional recovery, and overall enhancing the quality of life. The primary diagnosis that causes a deteriorating hip is a crucial factor to consider, as research has demonstrated its influence on the overall result.[2]

Prosthetic designs for THA have undergone continuous evolution since the late 1800s. Dr. Themistocles Gluck conducted preliminary animal experiments to explore different options for joint replacements.[3] Modern THA techniques have developed to include femoral and acetabular components that are inserted using a press-fit method.[4] Typically, femoral stems can be classified as either press-fit or cemented.[4,5]

The gold standard technique for achieving fixation of the femoral prosthesis during primary total hip arthroplasty remains a subject of ongoing discussion. The use of press-fit fixation has become increasingly popular in the past twenty years and is now the prevailing method employed in North America. This shift is partly attributed to historical evidence indicating suboptimal results with certain cemented femoral stem designs. Nevertheless, if the osseous integration of a femoral stem is delayed from the beginning, it will result in a delayed restoration of function and recovery. This phenomenon is more frequently observed in elderly patients with diminished bone density. A more significant issue lies in the significant complications linked to the use of press-fit femoral fixation, such as the loosening of components

and fractures in the femur. Registry studies [6–8] have demonstrated an elevated rate of revision and complications in this particular group of patients.

Through a comprehensive analysis of studies on cemented stem procedures, with a follow-up period of up to 20 years, it was discovered that among patients over the age of 50, the rate of successful outcomes in preventing infection-related loosening of the stem ranged from 86% to 98%.[9] Furthermore, an analysis encompassing multiple national joint arthroplasty registries revealed that among patients aged 75 years and above, the utilization of cemented fixation has been linked to a reduced likelihood of requiring revision compared to uncemented fixation.[10] Nevertheless, the registries from 2006 to 2010 have indicated a rise in the utilization of uncemented fixation. Troelsen et al[10] coined the term "Uncemented Paradox" to describe this phenomenon.

The initial justification for the development of press-fit fixation was to cater to the increased requirements of younger patients undergoing joint arthroplasty. The occurrence of cement failure was found to be irreversible and a progressive phenomenon that is more frequently observed in this specific patient population. The reason for the change in practice, despite improvements in cementing technique, may be attributed to the advancement of the concept of biological fixation. This shift in healthcare was accompanied by a drive to achieve expedited recuperation and minimize surgical trauma through the adoption of minimally invasive surgical techniques.[11] Consequently, there has been a resurgence of interest in the DA approach with certain adaptations from the initial explanation provided by Smith-Petersen.[1] The recognized advantage of the DA approach, due to its ability to spare muscle tissue, is the early restoration of function.

In order to evaluate the practical advantages of the DA approach in comparison to cemented arthroplasty, I performed a retrospective case-control study on a cohort of patients who had received hip replacement comparing the outcomes (e.g., incidence of loosening and post-operative fractures) of two commonly used surgical approaches.

Methods

This study is a retrospective case-control analysis that compares two groups of patients, both of which were treated during the same time period and in consecutive order. The study includes a total of 341 patients, with a total of 360 hips being evaluated. The study received approval from our Institutional Review Board under the exempt research category, which waived the need for informed consent. After observing multiple fractures around the artificial hip joint soon after surgery and considering information from research studies and data collected in registries, the authors created a protocol for achieving cemented fixation of the femoral component in patients who were identified as having an increased risk of falling or weakened femoral bone. A simplified cementing technique, as recommended by Müller, was regularly employed. From 2016 to 2018, the authors provided treatment to 146 patients using a cemented Avenir stem (Zimmer Biomet, Warsaw, IN). Additionally, 195 patients were treated with a comparable uncemented stem, Taperloc (Zimmer Biomet), which had a Müller-type design, within the same timeframe. The stems possess a comparable flat-wedge morphology, initially devised by Müller in 1970.[2] The initial Müller cement concept involved the use of cement as a filler for bone locking purposes. The ingrowth stem employs a titanium porous plasma spray surface for biological fixation, utilizing the same locking principle. It is available with either a 123° or 133° head neck angle, two offsets, and a type I taper. The cemented stem is made of

highly polished stainless steel and has a smooth surface, with a surface roughness (μRa) of less than 1 micron. It has a head neck angle of 135° and features two offsets and a taper of 12/14. All the heads were made of Biolox delta ceramic material (CeramTec Medical, USA).

Both groups underwent surgical procedures performed by orthopedic surgeons using the DA approach on the Hana table (Mizuho OSI, CA) with the assistance of fluoroscopic guidance. Both groups were subjected to the same multimodal pain program, which involved the use of Exparel (Pacira BioSciences, USA), a long-acting bupivacaine liposome injectable suspension and scheduled analgesics. The objective of this program was to reduce the use of opioids. Every patient was admitted to a specialized joint arthroplasty service, where they received the same standardized treatment protocols. The post-operative protocols were deployed on the day of the surgical procedure and released to their residence within a period of 24 to 48 hours. The postoperative follow-up involved conducting clinical evaluations and taking radiographs at six-week and six-month intervals following the surgery.

Surgical Approach and Protocol

The bone preparation procedure was identical for both groups, employing a technique known as "broach-only." This involved removing any loose cancellous bone and ensuring that the implant made full contact with the endosteal cortex in the medial/lateral dimension, thereby achieving complete canal filling. The canal fitting for the uncemented stems was a snug press-fit, designed to prevent sinking or subsidence and ensure immediate stability. The canal suitable for the cemented stem exhibited stable bone contact, which was adequate to prevent any movement of the stem. This phenomenon, as described by Müller, is known as "bone locking". The determination of femoral anteversion was based on the morphology of the canal for both stems.

The cementing technique utilized was "third generation" method, which involves using a disposable set of instruments for cement application (Zimmer Biomet). The process of broach preparation involved the removal of loose cancellous bone, followed by brushing the canal and using pulsed irrigation with suction lavage to eliminate fatty marrow contents and bone debris. Prior to cementing, the fluoroscopy was used to examine the ultimate position of the broach in the femur. A polymethylmethacrylate (PMMA) cement restrictor was positioned at a depth of 1 to 2 cm below the tip of the stem, measured from the last rasp, to match the final size of the stem. An optimal snug fit was required to enable the pressurization of the cement into the remaining cancellous spaces. The canal was desiccated using an absorbent material. The cement was thoroughly mixed under vacuum in the cement gun and then injected by reverse filling the femur form the plug, starting from the distal end and moving towards the proximal end using a long nozzle. During this process the nozzle achieved pressurization with canal blocking adapter to apply pressure to the cement to encourage cement interdigitation into the bone. The chosen stem was inserted then into the canal filled with cement during the initial dough phase, and pushed to the predetermined level of insertion, effectively securing it in place. Once the hip was determined to be adequately stable, it was placed back into the acetabulum while the cement was undergoing polymerization. Fluoroscopy was used to reexamine the femur following the cementing procedure. When using a cemented stem, it is possible to decrease the size of the stem in order to modify the version and leg length during the cementing process. In this scenario, the stem would not be interlocked with the bone and would need to be held in place until the cement had fully hardened.

Patient information. The average age in the press-fit group was 75 years, while in the cemented group it was 76 years. Among all the patients, 70% were females (Table I). Both groups were primarily diagnosed with osteoarthritis, femoral neck fracture, or avascular necrosis. Three adult reconstruction surgeons with specialized training in radiology conducted the evaluation. This involved assessing the bone quality using the Dorr classification, which categorizes bone density into three distinct types: cortical, corticocancellous, and cancellous, aiding in the assessment of bone strength and suitability for implantation.[3] Furthermore, the interface was analyzed according to Gruen zones, and the position of the plug and the orientation of the stem were observed.[4] The study documented surgical complications, with particular emphasis on issues related to cementing, such as fractures and loosening, as well as revision surgeries.

Table I. Demographic Data

Parameter	Total	Cemented	Press-Fit
Patients, n	341	146	195
Hips, n	360	157	203
Sex, Male: Female	102: 239	24: 122	78: 117
Mean age		76	75
Mean Follow-up		1.3 (0.0-3.9)	1.5 (0.1-4.4)

Quantitative analysis. The statistical analysis for the two cohorts involved the use of a two-tailed, paired Student's t test. Statistical analysis assumed an alpha level of 0.05 for determination of significance and was performed using Microsoft Excel 2002 (USA) and SPSS v. 25 (IBM, USA).

Results

The average duration of postoperative follow-up for patients in the press-fit group was 1.5 years, with a range of 0.1 to 4.4 years. For patients in the cemented group, the average duration was 1.3 years, with a range of 0 to 3.9 years (Table I). Out of the two groups, the press-fit group encountered eight femoral complications after surgery, whereas the cemented group did not experience any. The complications consisted of six fractures (2.95%) and two instances of femoral stem loosening (0.99%). All fractures were observed within the initial 31 days, with an average of 14.5 days (ranging from 2 to 31). The loosening was observed at 189 and 422 days after the surgery. Revision was necessary for all complications related to postoperative implants.

All fractures in the press-fit group were classified according to the Vancouver system, which was developed to distinguish between the varying types of periprosthetic femur fractures with respect to location, stability, and bone stock, as B2 periprosthetic fractures as detailed in Table II.[5] The patients underwent open reduction and internal fixation (ORIF) as well as femoral component revision using a long-stem prosthesis. The patients' femoral morphology was classified as either type-A (n = 2) or type-B (n = 4) according to the Dorr classification system. The average duration of surgery for the groups using cemented and press-fit techniques was 2.1 and 2.0 hours, respectively.

Table II:

Vancouver classification of postoperative periprosthetic femur fractures

Type	Subtype	Description	Treatment
A	A L	Lesser trochanter	Conservative (consider ORIF if large segment of medial cortex involved)
	A G	Greater trochanter	Conservative with abduction precautions (consider ORIF if displaced > 2.5 cm)
B	B1	Well-fixed prosthesis	ORIF with or without cortical strut allograft
	B2	Prosthesis loose	Revision THA with long-stem prosthesis
	B3	Prosthesis loose with poor bone stock	Revision THA and augmentation of bone stock with allograft versus oncologic prothesis
C		Fracture well below tip of the prosthesis	ORIF

Cement Findings

The analysis focused on the stem and plug position, anteroposterior (AP) fill, cement mantle white out, radiolucency, and subsidence in patients who were part of the cemented group. The majority of patients in this group had a neutral stem position, while five patients were in valgus position and seven patients in the varus position.

The average plug position, measured as the distance between the tip of the femoral stem and the cement base, was 22.6 mm, ranging from 0 to 92 mm. A total of 132 patients (85%) in this group exhibited whiteout of the cement mantle, while approximately 141 patients (91%) achieved complete anterior-posterior fill. Approximately 19 patients (12%) exhibited radiolucency, while no patients displayed subsidence. Based on the Dorr classification system, the majority of patients in the cemented series exhibited type-B morphology, with type-C and type-A bone types following in frequency.

Discussion

Multiple registry studies have demonstrated that press-fit femoral arthroplasty in total hip arthroplasty (THA), despite its widespread application, is linked to an increased risk of complications and revision, particularly in patients who are older and have poor bone quality.[6] Based on the current literature, our experience comparing press-fit and cemented fixation in two groups that were both contemporaneous and consecutive, using the DA approach, is consistent with the findings.[7] Due to the fact that the cemented cohort in this series did not experience any complications, it is recommended that cemented stems be utilized in a selective manner in patients who are at a high risk. Only a few radiolucencies were observed in the cement interface that was produced by the techniques that were utilized; however, the majority of the time, there was a complete "white out" that was consistent with a long-lasting bonding of the stem to the bone (Figure 1).

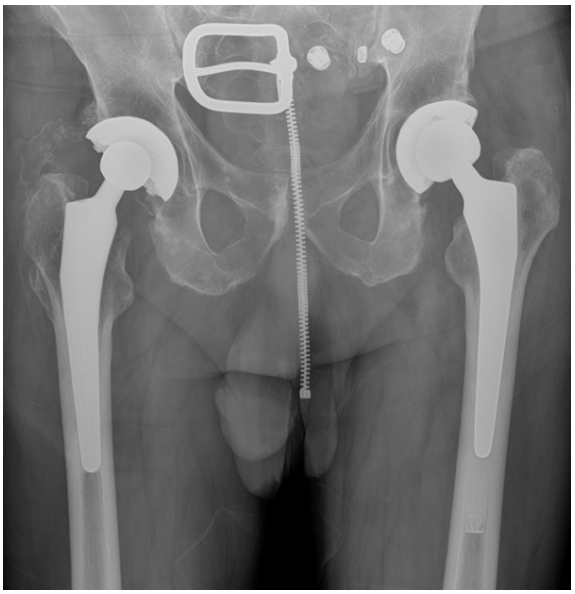
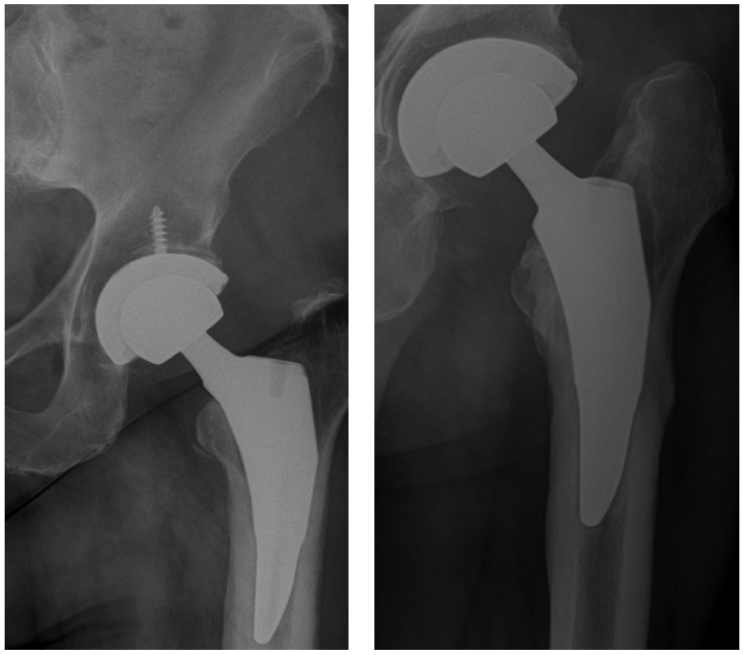
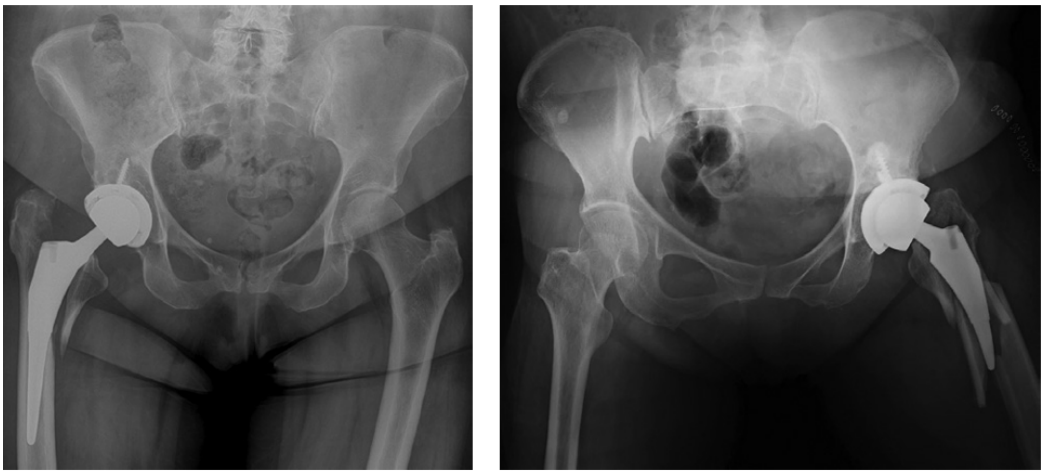


Figure 1: Comparison of cemented and cementless fixation



a b

Figure 2: a) Femoral stem loosening and b) femoral stem loosening



a b

Figure 3: a) Femoral stem fracture and b) femoral stem fracture.

According to this study, press-fit stems are particularly vulnerable in the early stages after surgery. Six fractures were observed, on average, 14.5 days (ranging from 2 to 31 days) after the operation (see Figure 2). There were no observed fractures after the 31-day period. There were no instances of fractures in any of the cemented stems during this same period. At the one-year mark, there were two uncemented stems that demonstrated poor fixation, while the cemented

group showed no signs of loosening (Figure 3). Tanzer et al[3] observed the same pattern of early failure in a report that analyzed data from the Australian registry. A comparison was made between cemented and press-fit femoral fixation from 1999 to 2015, specifically for patients aged 75 years and older. The study revealed that there were fewer instances of revisions within the first three months for patients who underwent cemented fixation. Wechter et al[13] demonstrated in a regional joint registry spanning from 1991 to 2011 that both press-fit and cemented stems had comparable rates of cumulative revision in patients aged 70 years and above. Purtill et al[14] conducted a study in the 1980s, where they treated a group of 123 patients aged between 80 and 89 years, utilizing the same uncemented stem as the one used in our study. There was only one instance of femoral revision for osteolysis, which was observed during a follow-up period ranging from 2 to 11 years.

Over the past few decades, significant advancements have been made in the postoperative care and rehabilitation protocols following THA. In the 1980s, the standard postoperative care for THA often involved prolonged immobilization, restricted weight-bearing, and extensive hospital stays.[14] However, with advancements in medical knowledge and technology, postoperative care has evolved to emphasize early mobilization, accelerated rehabilitation, and shorter hospital stays. Contemporary postoperative protocols now focus on early ambulation, progressive weight-bearing, and the use of multimodal pain management techniques. These changes aim to minimize complications such as venous thromboembolism, muscle atrophy, and joint stiffness while facilitating faster recovery and improved functional outcomes.[15] Surgeons' increased proficiency in press-fit fixation, along with the use of less invasive surgical techniques and higher patient expectations, has resulted in a quicker resumption of weightbearing and

reduced postoperative limitations. Furthermore, surgeons have recognized the straightforwardness of press-fit stem placement compared to cementing, which has led to the increased utilization of press-fit stems across various age groups and bone types, consequently leading to a significant decrease in the use of cemented stem fixation.

We implemented a simplified cementing technique with a Müller-type stem and bone-locking philosophy to address the growing demands for improved early recovery and reduced risks associated with press-fit fixation. Our findings demonstrate that this technique can be safely executed using the DA approach. The stem position and cement interface were optimally achieved, and no complications related to cement were identified. This shift in fixation philosophy aligns with the broader trend towards quicker recovery and enhanced patient satisfaction. While surgical innovations such as minimally invasive approaches and improved prosthetic designs have undoubtedly played a role in enhancing patient outcomes, the impact of optimized postoperative care cannot be overstated. Thus, a comprehensive approach that integrates both surgical innovation and optimized postoperative care is essential for achieving optimal results in THA patients.

There is a scarcity of research on cement technique and surgical approach. In 1980, Light and Keggi provided a description of utilizing a cemented stem in conjunction with the DA approach.[16] Macpherson et al[17] discovered that the posterior approach resulted in a more uniform cement layer around the bone compared to the anterolateral approach. They also proposed that the posterior approach provided easier access to the piriformis fossa. Menken et al[18] conducted a study on cemented stems using the DA approach. They highlighted the importance of a posterior

lateral entry point to ensure a 2 mm cement mantle and a centrally positioned stem in the canal. A "composite beam stem" was utilized, featuring a lateral flare and a distal centralizer. This stem design is not optimal for the DA approach, and it is challenging to begin the surgery from the posterior starting point down the femur using the anterior approach. The authors of this study aimed to position the stem in the canal, without the use of centralizers or a fixed starting point. This objective was consistently achieved for both cemented and press-fit stems. Utilizing intraoperative fluoroscopy enables prompt assessment of the position of the stem, thereby streamlining the cementing procedure. The Müller cementing technique utilized in this study results in direct contact between the implant and the bony canal, with regions of thin cement and areas where cement is not present.

In 1991, Jasty et al[19] examined 16 femora obtained post-mortem to investigate the initial mechanisms of loosening. The researchers determined that the process of loosening begins with the separation of the cement from the implant, followed by the development of fractures in the cement mantle. This phenomenon is more prevalent in regions where the cement is thin or contains voids. These studies have resulted in the development of the idea of a denser and unbroken layer of cement. Nevertheless, other studies did not demonstrate the same necessity for cementing. Nikolaou et al[5] examine the concept known as the "French paradox". In 2001, Havinga[20] discussed the clinical outcomes of two French design stems, namely the Charnley-Kerboull and the Ceraver Osteal. These stems were canal-filling cemented stems with thin cement areas, but they showed positive results. Claus et al.[21,22] conducted a registry-based analysis to identify risk factors for aseptic loosening of Müller-type stems. The study had a

minimum follow-up period of 16 years. The chrome cobalt alloy stems exhibited the highest performance, achieving a 94% survivorship rate over a 15-year period.

The cement technique employed was limited to a broach-only approach and utilized "second generation" methods, including cement plugging and gun injection, without the use of vacuum mixing, pulse lavage, or pressurization. Smaller stems had a higher likelihood of being revised for aseptic loosening when compared to larger stems, suggesting that a thicker cement mantle was not required for long-lasting fixation. The efficacy of employing a cementing procedure that aims to achieve a precise thickness of the cement mantle is inadequately substantiated in the existing body of literature and introduces additional time and intricacy to the surgical procedure. The "third generation techniques" employed in this series of the cementing process do not introduce any additional time or complexity. Furthermore, these techniques can be safely executed using the DA approach. The design of the stem is crucial, and the utilization of a Müller-type stem, as demonstrated here, is widely supported in the literature for both cemented and press-fit applications.

There are several restrictions that apply to this study. The review is retrospective, which means that it contains all of the inherent flaws that are associated with study designs of this kind. The objective result of complications and revision surgery was selected with the intention of reducing the amount of bias that was present. In addition, a study of this kind that is only conducted for a short period of time cannot make any claims regarding the long-term survival of press-fit or cemented stems. Nevertheless, there is a tremendous amount of published material that discusses the long-term effects of these kinds of stems.[21–25] One can reasonably anticipate

that an excellent cement appearance, such as the one described in this article, will deliver the same results as those indicated in other research that have been conducted on long-term survivorship. It is the employment of standard protocols by all surgeons, including equivalent intraoperative approaches, that is the primary strength of this study. This helps to reduce the number of factors that could potentially cause confusion between the two groups of patients.

Overall, the study showed that the use of the DA approach in modern cementing is effective. Additionally, femoral cementing resulted in fewer fractures and revisions compared to a contemporaneous uncemented series. This was observed in older patients who received the same patient care protocol and had a similar wedge-shaped stem design.

Future Directions

Our experimental results from the current study will form the basis of future research which will consist of a prospective study to follow long-term complications and mortality of press fit vs cemented stems in THA.

Compliance

This study was conducted using resources and information available from the medical practice of my mentor. The protocol was reviewed by the University of Texas Southwestern Medical Center Institutional Review Board . All subject data were de-identified for the purpose of our analysis. Security of our study data was accomplished by data encryption and storage as a computer file requiring 2 factor authentication.

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