THERAPEUTIC ADVANCES in
*Musculoskeletal Disease*

*Review*

# Hip replacement in femoral neck fractures: the role of cementation and its technical difficulties

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***Abstract*:** Hip fractures in elderly patients are an arising problem due to aging of population and still represent a controversial challenge for orthopedic surgeon who should help achieve the best functional recovery in the shortest time. Cementation in hip replacement plays an important role, but it should be carefully planned considering the possible risks. According to the literature, there are still no certainties regarding the superiority of an uncemented implant compared to a cemented one. The purpose of this work is to conduct an overview of the scientific literature that can clarify the advantages and disadvantages of cemented and non-cemented implants from a biological and biomechanical point of view.

***Keywords:*** cemented prosthesis, hip fracture, hip replacement, uncemented prosthesis

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## Introduction

Femoral neck fracture in frail elderly patients is increasing importance in the orthopedic care framework both for the resulting morbidity and mortality rate and for healthcare costs.[1,2]

Different classification systems for femoral neck fractures have been proposed. The system based on the anatomical classification divides femoral neck fractures in three regions: subcapital (the most frequent), transcervical, and basicervical. Since the subcapital and transcervical regions are intracapsular, the fracture characteristics of these regions are different from those of the basicervical region, which can be considered extracapsular. Intracapsular fractures present a high risk of osteonecrosis, a rarer complication in case of an extracapsular basicervical fracture.

According to the Garden classification, fractures are divided into four types. This classification is based on the degree of displacement of the fracture visible on radiographic examination in antero-posterior projection: Type I: incomplete or valgus-displaced fracture; Type II: complete fracture without displacement of the fracture fragments; Type III: complete fracture with partial displacement of the fracture fragments, with possible rotation of the femoral head in varus; Type IV: complete fracture with total displacement of the fracture fragments.

Total or partial hip replacement often represents a solution in medial neck fractures, favoring the recovery of autonomy and the resumption of a lifestyle that is satisfactory for the patient.[3]

The constant increase in the number of fractures per year, which is mainly determined by a progressive aging of the population, has certainly contributed to the constant evolution of research in this area, both in the mechanical field (drawing prosthetic, biomaterials, head size, and modular prostheses) and biological (coatings, couplings, and respect for tissues) in the attempt to prolong implant survival as far as possible.[4,5]

Case studies in the literature describe highly reliable results; despite this, implant failure is still a nightmare for orthopedic surgeons.

In this complex framework, there are still no certainties regarding the superiority of an uncemented implant compared to a cemented one.

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## Principles of hip replacement treatment

The most important goal of treating hip fractures in the elderly patient is to allow the earliest possible return to the activities of daily life through an early and multidisciplinary approach in order to avoid the complications related to the patient's bedtime. Medial fractures require a different therapeutic approach than lateral fractures.

Stable medial fractures (Garden I or II), regardless of the patient's age, are preferably treated by osteosynthesis with multiple screws or with sliding screw-plate with additional anti-rotation screw. The risk of nonunion or aseptic necrosis of the femoral head, typical complications of medial fractures, is limited, although ischemic suffering is possible. Loading can be granted quickly. Simple bed rest, followed by an early weight bearing compatibly with the pain, is a therapeutic choice that can be adopted in patients with high operative risk or in case of late diagnosis, but it is necessary to consider the risk of a possible secondary decomposition. In displaced medial fractures (Garden III or IV), the therapeutic approach varies according to the age and general condition of the patient. In the young patient (less than 60 years), the preferred option is to attempt the reduction of the fracture and the osteosynthesis with multiple screws, in order to save the joint. The patient should be informed of the high probability of complications (aseptic necrosis and pseudarthrosis), which may require prosthetic replacement surgery. In patients aged 60–75 years or with high functional demands and in good general conditions, the indicated intervention is total hip replacement which offers better results since it prevents the risk of damage of the natural acetabulum.[6,7] In the elderly patient (more than 75 years or with limited functional demands according to Karnofsky score or high operative risk), the preferred surgical option is the implantation of an endoprosthesis or partial hip prosthesis.

## Cemented or uncemented prosthesis

The partial or total hip replacement can be performed using a cemented, uncemented, or hybrid implant. Although the continuous evolution of surgical techniques and recent innovations in the field of biomaterial research ensure a good survival of the prostheses even 10–20 years after implantation, their failure always proves to be an important complication; in fact, prosthetic revisions are demanding, both for patients and for the surgeon, and have an important impact on determining the increase in health care costs. The most frequent cause of hip replacement failure is aseptic loosening. In cemented prostheses, compared to non-cemented ones, the phenomenon of stress shielding (the absorption of part of the load by the prosthetic implant and the consequent reduction of the biological activity of the bone, has less clinical relevance).[8–12]

Resorption generally occurs only after the increase of the space at the bone–cement interface by reaction to the debris. The cement was designed to fill the space between the bone and the smooth surface of the prosthesis, in order to achieve a uniform load transfer.[13,14]

From the 1960s to today, the use of polymethylmethacrylate (PMMA) cement has represented the 'gold standard' for the fixation of the prosthetic stem.[10] It is a vinyl polymer with viscoelastic properties that is obtained from the mixture at room temperature of a monomer (methylmethacrylate) and a polymer (prepolymerized particles of PMMA) in the presence of an initiator (benzoyl peroxide), an activator (nn-dimethyltoluidine) and a stabilizer (hydroquinone). Thanks to an exothermic reaction, PMMA is obtained, which has mechanical characteristics much lower than bone tissue: compressive strength of 50%–75% compared to cortical bone, tensile strength equal to 25% and fatigue resistance less than 50%. The PMMA cement is inserted between the stem of the prosthesis and the bone and solidifies until the implant and the bone are one single entity. Without cement, the fixation of the prosthesis only depends on bone regeneration at the interface and on the integration of the implant (osseointegration). A cemented prosthesis is a composite structure in which it is possible to recognize two interfaces: a cement–bone interface and a cement–prosthesis interface. The good result of the prosthesis over time will depend on the quality of these interfaces.

## Materials and methods

The optimal method of fixation of the prosthesis is controversial, leaving the choice of implanting a cemented prosthesis or not to the specialist's evaluations. Although it is agreed that the two methods are superimposable in terms of validity, some considerations must be made. For example, with reference only to pain relief, the postoperative clinical picture in the short term of cemented fixation guarantees more encouraging results. Mortality is practically identical in both surgical alternatives and, as regards the osteolytic processes that affect the prosthesis over time, it is not possible to make significant distinctions from radiographic investigations. Therefore, the choice of the cemented or uncemented option is related to the specific situation, even if some general guidelines should be considered.

Cemented prosthesis, in fact, allows an almost immediate walking with a rapid rehabilitation avoiding the complications due to the persistence of immobility. This solution is usually adopted in patients over the age of 75 or in those who have a poor bone quality or severe rheumatic diseases. There are not indications for patients who are severely overweight or particularly active (possible breakage due to the 'fatigue' of the cement).

Cementless prostheses, on the contrary, are made to adhere directly to the bone without the use of cement thanks to a peculiar conformation of the surface of the prosthesis stem that is able to encourage new formation of bone tissue around the point of contact. Considering that stabilization between the bone and the prosthesis takes place over a longer period of time, partial walking with the use of crutches will be mandatory for at least 1 month after the operation. This surgical approach is generally reserved for younger, more active patients with better bone quality, who generally undergo a total hip replacement.

In our analysis of the literature, in order to assess whether or not there is an optimal method of implant fixation in total or partial hip prosthesis (cementation or press-fit), we focused on the following issues about cementation and its technical difficulties:

- Biological risk related to cementation and mortality.
- Surgical time.
- Biomechanical risk with incidence of periprosthetic fractures and revision rate with relative healthcare cost.
- Hospitalization and recovery of hip function (Harris Hip Score).
- Rate of postoperative infections.

In our research, 75 articles were identified. After the full-text evaluation of 75 articles, 67 studies were excluded as retrospective studies, non-randomized uncontrolled studies and studies with results not in line with the scope of this review. No randomized controlled clinical trials (RCTs) were found about total hip arthroplasty cementation. The result was a total of eight selected RCTs about endoprosthesis cementation (Table 1).[15–22]

## Biological risk related to cementation and mortality

Bone cement implant syndrome (BCIS) is an important cause of intraoperative mortality and morbidity in patients undergoing cemented hip arthroplasty and can also occur in a minor postoperative form causing hypoxia and sensory alteration. This syndrome is characterized by hypoxia, hypotension, loss of consciousness, cardiac arrhythmia, and increased pulmonary vascular resistance (PVR) up to cardiac arrest. The proposed severity classification of BCIS includes the following grades:

- Grade 1: moderate hypoxia (SP02 $<$ 94%) or hypotension (reduction in systolic pressure $<$ 20%).
- Grade 2: severe hypoxia (SpO2 $<$ 88%) or hypotension (pressure drop $>$ 40%) or unexpected loss of consciousness.
- Grade 3: cardiovascular collapse with the need for cardiopulmonary resuscitation.

The etiology and pathophysiology of BCIS are not fully known. Several mechanisms have been proposed. The first formulated theory is based on the release into blood circulation of cement monomers during cementation. More recent studies have enlightened the role of embolization during cementation and insertion of the prosthetic stem. Various mechanisms have been hypothesized such as histamine release, complement activation, and vasodilation by releasing endogenous cannabinoids. It has been shown that circulating methylmethacrylate monomers cause vasodilation in vitro. Recent research has focused on the role of BCIS embolization. The physiological consequences of embolization are considered to be the result of both a mechanical effect and the release of mediators that causes an increase in pulmonary vascular tone. It has been shown that these fragments consist of fat, bone marrow, cement fragments, bone fragments, and aggregates of platelets and fibrin. Embolization is the

**Table 1.** RCT about cementation of endoprostheses.

| Authors | Year | Sample | Mean age | Outcome parameters |
|---|---|---|---|---|
| *Moerman et al.*[15] | 2017 | 201 (91 UC/110 C) | 84.0/83.0 | Complications, 12 months post op mortality, surgical time, hospitalization, revisions |
| *Langslet et al.*[16] | 2014 | 220 (108 UC /112 C) | 83.0/83.4 | 12 months post op mortality, surgical time, hospitalization, HHS score |
| *Talsnes et al.*[17] | 2013 | 334 (172 UC/162C) | 84.0/84.3 | Complications, surgical time, revisions |
| *Vidovic et al.*[18] | 2013 | 79 (41 UC/38 C) | 82.04/82.9 | Complications, 12 months post op mortality, surgical time, hospitalization, revisions, HHS score |
| *Taylor et al.*[19] | 2012 | 160 (80 UC/80 C) | 85.1/85.3 | Complications, 12 months post op mortality, surgical time, hospitalization, revisions |
| *Deangelis et al.*[20] | 2012 | 130 (64 UC/66 C) | 82.8/81.8 | Complications, 12 months post op mortality, surgical time, hospitalization |
| *Parker et al.*[21] | 2010 | 400 (200 UC /200 C) | 83.0/83.0 | Complications, 12 months post op mortality, surgical time, hospitalization, revisions |
| *Emery et al.*[22] | 1991 | 53 (26 UC/27 C) | 79.6/78.0 | Surgical time, hospitalization, HHS score |

C, cemented; HHS, Harris Hip Score; UC, uncemented.

result of the high intramedullary pressures that develop during cementation and insertion of the prosthesis. The cement which undergoes an exothermic reaction and with expansion in the space between the prosthesis and the bone causes the trapping of air and the medullary contents which are pushed under pressure with force into the circulation. The temperature of the cement can rise up to 168°C after mixing its components. BCIS has a broad spectrum of severity. Many patients undergoing cemented hip arthroplasty develop a non-fulminant BCIS characterized by a significant but transient reduction in arterial saturation and systemic blood pressure. A lower percentage of patients present with fulminant BCIS with strong intraoperative cardiovascular changes that may precede arrhythmias and shock.

Several patient risk factors have been involved in the onset of BCIS: advanced age, pre-existence of poor functional reserves, impaired cardiopulmonary function, pre-existing pulmonary hypertension, osteoporosis, bone metastases and concomitant hip fracture, especially pathological fractures or intertrochanteric. These last three factors are accompanied by an increase in the vascular channels through which the medullary contents can migrate into the circulation. A patient with a previously untreated medullary canal may be at a higher risk of developing the syndrome than those undergoing surgical revision. Two mechanisms are possible. First, there is a greater amount of potentially embolic material in an untreated femur; second, once the canal has been treated and cemented, the internal surface of the femur is smoothed and sclerotic and offers reduced permeability. The use of a prosthesis with a long stem increases the possibility of developing a BCIS. Anesthesiologists must be involved in the preoperative evaluation of the patient scheduled for hip replacement surgery, for a complete study of comorbidities and their optimization. Particular attention must be aimed at heart-failured patients, respiratory-failured patients, and metastasized patients undergoing surgery with the use of cement or for whom the insertion of a long stem prosthesis is planned. In high-risk cases, it is important to work as a team between surgeon and anesthetist to discuss the most suitable anesthetic and surgical techniques, including the possible risks and advantages of an uncemented prosthesis compared to a cemented one.

The review of the literature demonstrated that the difference in intraoperative complication rates in patients undergoing cemented and uncemented total or partial hip prostheses is not statistically significant. Despite the incidence of minor complications such as modest reductions in blood pressure and saturation during cementation is quite widespread (25–38%), BCIS and cardiovascular collapse are rather rare complications (0.1–0.4%) especially if special precautions are taken in the preoperative phase (avoid cementation in patients with severe underlying cardiorespiratory pathology). Although there is no clear evidence on the impact of the anesthetic technique on the severity of BCIS, the most recent studies have suggested that inhalation anesthetics are associated with greater haemodynamic changes for the same embolic load. Consideration should be given to avoiding the use of nitrous oxide in high-risk subjects to avoid exacerbation of air embolism. The increase in the inspiratory oxygen concentration must be taken into consideration in all patients at the time of cementation, especially in those at the highest risk of BCIS. Avoiding the reduction of intravascular volume can reduce the extent of the hemodynamic changes of the BCIS.

In terms of perioperative and 12-month mortality, the reviewed studies showed the absence of significant differences between cemented or uncemented prostheses.

### Surgical time

Literature usually considers the duration of the surgery, meaning the 'surgical time' the so-called skin-to-skin time of the operation. It has been shown that the intervention time of cemented arthroplasty is longer than that of non-cemented ones in terms of 9 to 10 minutes on average, the strictly necessary time for the processing of the cement, even if on a large scale this time difference did not appear statistically significant.

### Biomechanical risk with incidence of periprosthetic fractures and revision rate with relative healthcare cost

In the last 10 years, the scientific literature has underlined how the cementation of prostheses can represent a valid method of implant fixation as it is linked to a lower risk of periprosthetic fractures and revisions for loosening (with savings on costs related to hospitalization) and faster recovery of mobility with greater patient satisfaction.

It is known that four types of periprosthetic hip fractures are identified with a different percentage incidence in relation to the time of onset: intraoperative fractures, early postoperative fractures, late postoperative fractures, and pathological fractures.

In intraoperative ones, the incidence varies between 0.1% and 4%, reaching up to 6–8% in case of revision and the determining risk factors are: female sex, poor bone quality (osteoporosis, osteolysis), previous interventions, undersizing of the rasp (2 mm) compared to the final prosthesis, excessive attempt to 'press-fit' if it is decided not to cement the stem, bone deformities, prosthesis morphology not suitable for the anatomy of the femur.

In early postoperative operations (within the first 6 months of surgery), the risk factors are represented by cementless prostheses with unrecognized intraoperative femoral fractures and stem of insufficient length in revision surgery. In late postoperative operations, the incidence is lower and varies from 0.1% to 2.5%; the risk factors are represented in 84% of cases by minor injuries, while only 4% by major injuries.

It becomes clear that predisposing factors, such as aseptic loosening with the formation of areas of osteolysis and resorption, favor bone failure, and consequent fracture.

Pathological fractures are caused by breast or prostate cancer metastases and are very rare due to the age of the prosthetic patients.

A few studies have shown that cemented implants have a lower risk of intraoperative fractures in relation to the lower friction stress that is generated on the endosteum at the moment of the insertion. However, it is important to be careful during cementation, making sure that the cement completely covers the stem in order to avoid the appearance of 'air bubbles' at the cement–bone interface and above all cement-prosthesis. In fact, this is the first actor in cases of prosthetic loosening.

Aseptic revision is defined as any re-intervention performed after the primary procedure involving an implant that failed for reasons other than infection (loosening or periprosthetic fracture).[22,23] In a multi-variable analysis, patients undergoing cementless prosthesis were shown to have a higher risk of aseptic revision (cumulative risk 1 year after first implant surgery). This difference in the rate of aseptic revisions was primarily attributed to a different incidence of periprosthetic fractures (greater in patients with uncemented than cemented endoprostheses – 1.6% *vs* 0.2%). These results suggest that the best outcome associated with cemented hemiarthroplasty implanted for fracture should also be considered also if cementless fixation is the method of choice in elective total hip arthroplasty.

The specific reasons for the improved outcomes in patients undergoing cemented hemiarthroplasty have not been definitively elucidated. However, one theory is that cemented fixation may better resist periprosthetic fracture among patients with major risk factors such as older age, osteoporosis, and history of repeated falls.[24,25] From the analysis of the literature, it seems to emerge that an uncemented stem is more easily subjected to torsional stress and the rotational forces generated in the canal due to reduced articular excursions of the dome can lead to a progressive mobilization of the stem or to long spiroid periprosthetic fractures. In addition, in the long term, an uncemented stem is subject to periprosthetic bone resorption phenomena. In the face of the most recent studies, the American Academy of Orthopedic Surgeons Clinical Practice Guideline on the management of hip fractures in the elderly recommends the use of cemented femoral stems in patients undergoing arthroplasty for hip fractures.

In addition to the reduced risk of periprosthetic fracture, cementation appears to be associated with a better restoration of some biomechanical parameters that are necessary for a successful implant: femoral offset, lateralization, and limb length.

## Hospitalization and recovery of hip function (HHS)

No difference in hospital stay times was demonstrated when comparing patients undergoing cemented and non-cemented hip prostheses.

A few studies provided information on hip function after surgery as assessed according to the HHS. The topics covered by this rating scale are pain, functionality, absence of deformity and range of motion of the joint. The pain measures the severity of pain and its effect on activities and the need for pain medication. The function consists of daily activities (use of stairs, use of public transport, and sitting and handling of shoes and socks) and gait (lameness, necessary support, and walking distance). The deformity takes into account hip flexion, adduction, internal rotation, and limb length discrepancy. Range of motion measures hip flexion, abduction, external and internal rotation, and adduction. The score has a maximum of 100 points (best possible result) covering pain (1 item, 0–44 points), function (7-item, 0–47 points), absence of deformity (1 item, 4 points) and range of motion (2 items, 5 points).

A weakly significant difference in HHS values was demonstrated in patients undergoing cemented versus non-cemented endoprostheses. In general, the HHS score is better in cemented endoprostheses due to the earlier mobilization of the patient with a faster resumption of walking. No statistically significant difference was shown in total hip replacement. It is important to consider that the timing of administration of the evaluation scale in the postoperative period influences the score, representing an important bias in this type of evaluation.[26,27]

## Rate of postoperative infections

The global incidence of deep tissue infections in the population of cemented prostheses is around 2.1% compared to 1.4% in the non-cemented group. Superficial wound infections occur in 1.5% of cases in the cemented group and in 1.7% of cases in the uncemented group. The incidence of urinary tract infections and pneumonia was 1.8% and 3.6% in the cemented group and 2.2% and 5% in the uncemented group, respectively. Given these data, we can state that there are no statistically significant differences between the two groups regarding the onset of infections. The prolongation of the operative time during cementation could represent a risk factor for infections but the difference in the surgical timing is not significant (on average 9–10 minutes). In addition, the use of antibiotic-containing cements can reduce the risk of infections. The antibiotics that can be used in cement are different and include penicillin, gentamicin, erythromycin, cephalosporin, tobramycin, vancomycin, cefuroxime, oxacillin, and colistin. However, the antibiotic present in the cement must be thermo-stable, so as not to go against structural and therefore functional changes following the exothermic polymerization reaction of the acrylic cement itself. Although antibiotic-coated cement has the advantage of reducing the risk of a periprosthetic infection, the use of this material could have potential clinical disadvantages. The main disadvantages are the development of an allergic reaction, local and systemic toxicity, changes in the mechanical properties of the cement, and the onset of antibiotic-resistance phenomena. Furthermore, the use of cement stabilizes the implant and allows for faster mobilization of the patient and makes him able to recover his autonomy in a shorter time. This exposes him to a lower risk of complications due to bed rest (pneumonia due to prolonged bed rest, urinary tract infection from persistent bladder catheter).

## Conclusion

Hip fractures in elderly patients still represent a controversial challenge for orthopedic surgeon who should help achieve the best functional recovery in the shortest time. In the recent past, due to the increase of experience with cementless total hip arthroplasties (including short conservative stems), they have been used in proximal femoral fractures, more and more with good results.[28] Cementation plays an important role, but it should be carefully planned considering the possible risks.

According to the literature, most of the parameters taken into consideration are comparable in cemented and uncemented hip total or partial hip prostheses.

In particular, cementation of the stem is not connected to an increase in the duration of the operating time or to a worse outcome in terms of complications and postoperative infections if the surgical procedure is correctly planned with the anesthesiologist who assesses the risk. On the contrary, cementation allows a more rapid recovery of the patient's motility who can assume the upright position the day after surgery. Cemented implants can be used in revision hip surgery after the osteosynthesis failure, but in these cases, some problems could rise due to cement penetration in residual screws' holes out of the bone.[29]

A reduced incidence of fracture events and mobilization of the prosthetic stem has also been demonstrated in cemented implants. All this suggests cementing the prosthetic stem in all cases where there are no obvious cardiovascular comorbidities with severe intraoperative risk and where the surgeon has mastered the technique.

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### *Ethics approval and consent to participate*

Not applicable.

### *Consent for publication*

Not applicable.

### *Author contributions*

**Elena Gasbarra:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing – original draft.

**Eleonora Piccirilli:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing – original draft.

**Chiara Greggi:** Data curation; Formal analysis; Writing – original draft.

**Flavio Trapani:** Conceptualization; Data curation; Formal analysis; Investigation; Writing – original draft.

**Riccardo Iundusi:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Writing – original draft.

**Umberto Tarantino:** Conceptualization; Data curation; Formal analysis; Investigation; Supervision.

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