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Uncemented short stems in primary total hip arthroplasty: the state of the art

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- Over the last two decades, several conservative femoral prostheses have been designed. The goals of conservative stems include: the spearing of the trochanteric bone stock; a more physiological loading in the proximal femur reducing the risk of stress shielding; and to avoid a long stem into the diaphysis preventing impingement with the femoral cortex and thigh pain.
- All stems designed to be less invasive than conventional uncemented stems are commonly named 'short stems'. However, this term is misleading because it refers to a heterogeneous group of stems deeply different in terms of design, biomechanics and bearing. In the short-term follow-up, all conservative stems provided excellent survivorship. However, variable rates of complications were reported, including stem malalignment, incorrect stem sizing and intra-operative fracture.
- Radiostereometric analysis (RSA) studies demonstrated that some conservative stems were affected by an early slight migration and rotation within the first months after surgery, followed by a secondary stable fixation. Dual-energy x-ray absorptiometry (DEXA) studies demonstrated an implant-specific pattern of bone remodelling.
- Although the vast majority of stems demonstrated a good osseointegration, some prostheses transferred loads particularly to the lateral and distal-medial regions, favouring proximal stress shielding and bone atrophy in the great trochanter and calcar regions.

Keywords: total hip arthroplasty; uncemented; short stems; outcomes

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Introduction

In many countries, such as in North America, Australia and the southern region of Europe, cementless fixation represents the most common technique used in total hip arthroplasty (THA).[1,2] Although some authors have advocated the superiority of cemented fixation over uncemented fixation,[3,4] conventional uncemented stems have shown excellent results in the long term.[5,6] However, they could be associated with reduction of the trochanteric bone stock and thigh pain due to the invasion of the femoral shaft.

Over the last two decades, several conservative femoral prostheses have been designed and some authors advocated their use, particularly in young patients with high-activity recreational interests.[7,8] The goals of conservative stems include: the spearing of the trochanteric bone stock; a more physiological loading in the proximal femur reducing the risk of stress shielding; and to avoid a long stem into the diaphysis preventing impingement with the femoral cortex and thigh pain.[9,10]

All stems designed to be less invasive than conventional uncemented stems are commonly named 'short stems'. However, this term is misleading because it refers to a heterogeneous group of stems deeply different in terms of design, biomechanics, principles of fixation and bearing. In this respect, several classification systems for femoral stems have been developed, taking into account features such as length of the stem, location of loading, osteotomy level for the neck resection and implant fixation principles (Table 1).[11–15] McTighe et al[11] proposed the term 'short' for stems that do not extend below the metaphyseal region of the proximal femur. In this respect, they proposed three types of stems: head stabilized (resurfacing); neck stabilized; and metaphyseal stabilized. Recently, Khanuja et al[12] classified short stems according to fixation principles and location of proximal loading. The authors distinguished four categories: femoral neck fixation; calcar loading; lateral flare and calcar loading; and shortened tapered stems. In this classification system, resurfacing was not included.

The purpose of the present paper is to provide an overview of the most common conservative stems, describing their features and analysing their clinical and radiological results.

Table 1. Classification systems for femoral stems

Authors (year)	Classes	Description	Rationale
McTighe et al[11] (2013)	• Head stabilized • Neck stabilized • Metaphyseal stabilized • Conventional (metaphyseal/ diaphyseal) stabilized	• Resurfacing. • Short curved neck-sparing stems, and standard-length stems preserving femoral neck, but engaging the neck, metaphysis and diaphysis. • Short metaphyseal stems including anatomical, straight and tapered designs. • Conventional stems engaging both metaphysis and diaphysis.	Assessment of length and method of achieving primary stability of the stem.
Feyen and Shimmin[14] (2014)	• Type I • Type II • Type III • Type IV • Type V	• Resurfacing. • Mid-head resection stems. • Short stems with subcapital (IIIA) or standard (IIIB) osteotomy. • Traditional stems. • Diaphyseal fixation stems.	Assessment of the osteotomy level for the neck resection and implant fixation principles.
Van Oldenrijk et al[15] (2014)	• Collum • Partial collum • Trochanter-sparing	• Conical or cylindrical ultra-short stems, with complete anchorage in the femoral neck. • Partial femoral neck-sparing curved designs. • Trochanter-sparing but not neck-sparing, and shortened tapered stems.	Assessment of the osteotomy level for the neck resection and implant fixation principles.
Khanuja et al[12] (2014)	• Type I • Type II • Type III • Type IV	• Femoral neck fixation stems (from IA to IC according to the stem geometry). • Calcar loading stems (from IIA to IID according to the stem geometry). • Calcar loading with lateral flare stems. • Shortened tapered stems.	Assessment of location of loading and implant fixation principles.
Falez et al[13] (2015)	• Collum • Partial collum • Trochanter-sparing • Trochanter-harming	• Conical or cylindrical ultra-short stems, with complete anchorage in the femoral neck. • Partial femoral neck-sparing curved designs. • Trochanter-sparing but not neck-sparing, and shortened tapered stems. • Short stems interrupting the circumferential integrity of the femoral neck section and violating trochanteric region.	Assessment of the osteotomy level for the neck resection and implant fixation principles.

Inclusion criteria and study collection

A comprehensive search of PubMed, Medline, CINAHL, Cochrane, Embase and Google Scholar databases was performed, using various combinations of the following keywords: 'short stem'; 'conservative stem'; 'metaphyseal'; 'neck-sparing'; 'trochanter-sparing'; 'uncemented'; and 'total hip arthroplasty'.

All peer-reviewed journals were considered and all articles reporting outcomes of primary total hip arthroplasty performed with short stems were analysed. A cross-reference research of the selected articles was also performed to obtain other relevant articles for the study. Finally, a search of every prosthesis according to the name of the implant was performed.

In the present review, we did not include all the conservative stems available for clinical practice. We defined as 'short' all the stems having fixation in the neck and engaging the metaphysis and diaphysis, or in the metaphysis with or without engagement of the proximal part of the diaphysis. Studies investigating hip resurfacing or femoral neck implants and stems with extramedullary anchorage systems such as the thrust-plate prosthesis were excluded.

To be included in this review, a study had to be published in a peer-reviewed journal, to investigate a short uncemented stem, to provide survivorship of the implant and report complications or revision rates, and to have a minimum follow-up of one year. Radiostereometric analysis (RSA) and dual-energy x-ray absorptiometry (DEXA) studies performed on short stems were also included.

Stem features and outcomes

Collum femoris preserving (CFP)

The CFP (Waldemar Link) is an uncemented neck-retaining stem (Fig. 1). It is made of a Tilastan® alloy with a 70-μm microporous surface provided with a 20-μm hydroxyapatite coating, but the distal third is smooth. The primary stability of the stem is achieved by the contact with the calcar and the lateral femoral cortex, and longitudinal ribs enhance the rotational stability.

The CFP stem demonstrated a mean survivorship of 98.8% (95.8% to 100%) with aseptic loosening as the endpoint, at a mean follow-up of seven years (2 to 17) in 1657 hips.[16–32] The mean Harris hip score (HHS) was 89 points (49 to 99) at the final follow-up assessment in 1024 hips,[16,18,22–24,30–32] while the mean incidence of thigh pain was 1.6% (0% to 11%) in 741 hips.[16,17,22,25,26,28,31] The mean intra-operative periprosthetic fracture rate was 3.3% (0% to 13.3%) in 1247 hips, whereas the mean coronal stem malalignment rate was 18.8% (5.2% to 60%) in 574 hips. The mean incidence of incorrect stem sizing was 10.4% (6.3% to 20%) in 596 hips.[16,22,23,28,31] The mean rate of > 2-mm stem subsidence was 5.3% (0% to 11%) in 444 hips[22,23,26,27,32] and the mean rate of stress shielding was 26.9% (5.2% to 66%) in 556 hips.[16,22,26,28,31]

Metaphyseal total hip arthroplasty (METHA)

The METHA (Aesculap) is an uncemented neck-retaining monoblock or modular stem (Fig. 2). It is made of a titanium alloy with a proximal rough titanium, plasmasprayed,

Fig. 1 CFP stem at ten years of follow-up.

Fig. 2 METHA stem at eight years of follow-up.

microporous surface coated with 20-μm dicalcium phosphate dihydrate (CaHPO4x2H2O). It has a proximal trapezoidal section providing a cortical multipoint contact. It loads medially on the calcar region and laterally on the proximal lateral cortex with its angulated distal end. This shape aims to enhance proximal load transfer in both medial and lateral sides.

The METHA stem demonstrated a mean survivorship of 95.9% (92% to 98%) with stem revision as the endpoint, at a mean follow-up of 4.5 years (2.8 to 5.8) in 556 hips.[33–36] Schnurr et al[37] investigated the METHA revision rate, distinguishing between monoblock and modular stems. In a population including 1090 monoblock stems, 314 modular stems with a titanium neck and 230 modular stems with a cobalt chrome neck, they reported a seven-year revision rate of 4.6% for both monoblock and modular cobalt chrome neck stems, and 7.5% for hips with modular titanium neck stems. The mean HHS at the final follow-up assessment was 92.2 points (89.9 to 97 points) in 632 hips with a mean follow-up of 4.1 years (2.7 to 5.8). In one study of 151 hips,[35] the authors evaluated the incidence of thigh pain, reporting no cases of severe or disabling thigh pain in the patient-administered questionnaire. The mean intra-operative peri-prosthetic fracture rate was 0.7% (0% to 2.4%) in 556 hips.[33–36] In one study of 250 hips,[36] the authors evaluated the coronal stem malalignment reporting valgus position (> 140°) in 5.6% of the hips, and varus position (< 130°) in 19.8%. The mean rate of > 2-mm stem subsidence was 1.3% (0.4% to 3.9%) in 550 hips[34–36,38] and the mean rate of stress shielding was 2.5% in 250 hips.[36]

Shin et al[39] compared the METHA stem with a conventional-length femoral stem (BiCONTACT, Aesculap) including 50 hips in each group matched for age, sex, body mass index (BMI), height, surgical approach and surgeon. The authors did not find significant differences between the two groups in terms of post-operative radiographic outcomes, functional outcomes or complications. However, the short stem was associated with a higher incidence of malalignment (4% *versus* 2%) and subsidence (2% *versus* 0%) and a lower incidence of thigh pain (0% *versus* 4%) compared with a conventional-length femoral stem. No patient in either group underwent revision surgery for aseptic loosening with a mean follow-up of 58 months (36 to 83).

Mayo

The Mayo (ZimmerBiomet) is a short, double-tapered stem. Its design provides a four-point fixation in the metaphysis, loading the calcar region and the lateral cortex of the proximal femur. It is made of a Tivanium® alloy with fibre metal pads for biological ingrowth. It is also available with and without a Calcicoat Ceramic Coating (HA/TCP) in the proximal part.

The Mayo stem demonstrated a mean survivorship of 95.4% (92.3% to 100%) with aseptic loosening as the endpoint, at a mean follow-up of 4.7 years (2 to 7.9) in 592 hips.[7,8,40–46] The mean HHS was 91 points (85 to 96) at the final follow-up assessment in 592 hips,[7,8,40–46] while the mean incidence of thigh pain was 1.6% (0% to 2.7%) in 250 hips.[8,42,44] The mean intra-operative peri-prosthetic fracture rate was 6.8% (0% to 12.1%) in 529 hips.[7,8,40,42,44–46]

Fig. 3 Proxima stem at five years of follow-up.

In two studies including 90 hips,[42,46] the authors evaluated the coronal stem malalignment reporting valgus position in 25.5% of the hips and varus position in 31.1%. The mean rate of > 2-mm stem subsidence was 3% (0% to 7%) in 302 hips[8,40,42–44] and the mean rate of stress shielding was 5.6% (4.1% to 6.7%) in 238 hips.[7,8,42]

Proxima

The Proxima (DePuy) is characterized by a tapered, trapezoidal geometry and lateral flare fitting with proximal femoral internal shape (Fig. 3). It is made of a titanium alloy with a rough titanium microporous surface coated with 30-μm thick hydroxyapatite except for the distal tip. It extends up to the junction between the metaphysis and diaphysis and provides a transfer load to the calcar and lateral cortex.

In one study enrolling 129 hips, the prototype design demonstrated a survivorship of 100% with aseptic loosening as the endpoint, at a mean follow-up of eight years.[47] The mean HHS was 95 points with no patients complaining of thigh pain. The rate of incorrect sizing of the stem was 23%.

The Proxima stem demonstrated a mean survivorship of 100% at a mean follow-up of 4.2 years (1.7 to 6.5) in 749 hips, with aseptic loosening as the endpoint.[48–55] The mean HHS was 92.2 points (86 to 98) at the final follow-up assessment in 749 hips,[48–55] with no authors reporting cases of thigh pain. The mean intra-operative peri-prosthetic fracture rate was 1.8% (0% to 3%) and the mean coronal stem malalignment rate was 15.7% (5.4% to 32.3%) in 749 hips.[48–55] The incidence of neck stress shielding was in the range of 50% to 100% in six of these studies. The mean rate of > 2-mm stem subsidence was 0.2% (0% to 0.8%). In one study including 65 hips,[53] the incidence of incorrect stem sizing was 53.8%.

Some authors compared this ultra-short stem with conventional uncemented stems,[50,56,57] including 354 hips in each group. At a mean follow-up of 5.9 years (1.5 to 11.8), the ultra-short stem showed no differences from conventional cementless stems in terms of validated functional outcomes scores or fixation, although lower risk of thigh pain and proximal stress shielding was reported. Some authors also compared the Proxima with a metaphyseal short stem[58] and an ultra-short non-anatomic stem.[59] In both studies, there were no significant differences between the two groups in terms of validated functional outcomes scores, incidence of thigh pain, revision rates, aseptic loosening rate and complication rates.

CUT

The CUT (ESKA Implants) is an uncemented neck-retaining modular stem (Fig. 4). It is made of a titanium alloy and its surface has a three-dimensional spongy metal structure (tripods). The shape of the prosthesis is straight and oval in the proximal part and curved in the distal part, becoming narrower at its tip in order to contact the calcar and the lateral femoral cortex.

The CUT stem demonstrated a mean survivorship of 96.4% (69.6% to 100%) at a mean follow-up of five years (3 to 8) in 690 hips,[60–67] with aseptic loosening as the endpoint. The mean HHS was 92 points (85 to 98) at the final follow-up assessment in 690 hips,[60–67] while the mean incidence of thigh pain was 2.9% (1% to 5.1%). The mean intra-operative peri-prosthetic fracture rate was 0.6% (0% to 2.4%) and the mean incidence of > 2-mm subsided stems was 3.4% (0.8% to 7.7%). Only the study performed by Steens et al[63] evaluated the coronal malalignment and the improper sizing of the stem resulting in 28% and 27.3% of the cases, respectively. On the other hand, only the study performed by Nieuwenhuijse et al[66] investigated the proximal stress shielding, reporting a rate of 12.8%.

Nanos

The Nanos stem (Smith&Nephew) is an uncemented neck-retaining stem (Fig. 5). It is made of a titanium alloy coated with calcium phosphate on approximately 75% of its surface. It is wedged in the sagittal and coronal plane with a curved distal end, providing a cortical multipoint contact and loading on both the calcar region and proximal lateral cortex.

The Nanos stem demonstrated a survivorship of 100% with stem revision for any reason as the endpoint, at a mean follow-up of 4.4 years (2.3 to 5.6) in 193 hips.[68–70] The mean HHS at the final follow-up assessment was 93.6 points (90 to 97 points) in 193 hips.[68–70] In two studies including 109 hips,[69,70] the authors

Fig. 4 CUT stem at three years of follow-up.

Fig. 5 Nanos stem at seven years of follow-up.

investigated the incidence of thigh pain reporting two cases (1.8%) of slight non-disabling pain, and the coronal stem malalignment reporting valgus and varus position in 1.8% of the hips, respectively. The mean intra-operative peri-prosthetic fracture rate was 1.5% (0% to 3.6%) in 193 hips.[68–70] Only one study including 37 hips[70] investigated the proximal stress shielding, reporting a rate of 27%.

Tri-Lock bone preservation system (BPS)

The Tri-Lock BPS (DePuy) is a short tapered-wedge stem. It is made of a titanium alloy with a highly porous and roughened coating (Gription®) in the proximal part.

Fig. 6 GTS stem at seven years of follow-up.

The Tri-Lock stem demonstrated a mean survivorship of 99.5% (99.2% to 100%) with femoral revision as the endpoint, at a mean follow-up of 3.4 years (2.3 to 5) in 475 hips.[71–73] The mean HHS was 86.5 points (85 to 88) at the final follow-up assessment, while the mean incidence of thigh pain was 12.3% (1.6% to 16%). In two studies including 415 hips,[72,73] the mean intra-operative peri-prosthetic fracture rate was 0.5% (0% to 1.6%) and the coronal stem alignment was valgus and varus in 20.5% and 7.5% of the hips, respectively. Amendola et al[73] also investigated the onset of cortical hypertrophy and femoral stress shielding, reporting an incidence of 2% and 64.5%, respectively. On the other hand, Albers et al[72] investigated the onset of stem subsidence, reporting an incidence of 39.8% with an average of 1.04 mm (0.5 to 5).

Global tissue sparing (GTS)

The GTS (ZimmerBiomet) is an uncemented monoblock stem (Fig. 6). It is made of a titanium-based alloy with a rough surface to promote bone ingrowth. The metaphyseal anchorage and rotational stability are provided by the tapered elliptic-octagonal cross-section of the stem, longitudinal anterior and posterior fins, and femoral bone compaction.

The GTS stem demonstrated a survivorship of 100% with femoral revision for any cause as the endpoint, at a mean follow-up of 1.9 years (1.4 to 2.3) in 229 hips.[74,75] The mean Merle d'Aubigné clinical score was 17.5 points at the final follow-up assessment. The intra-operative peri-prosthetic fracture rate was 0.9% in 229 hips. The coronal stem malalignment consisted in the varus position in 4.3% of the hips. In both studies, no cases of stem subsidence and proximal stress shielding were reported.

Fig. 7 Fitmore stem at seven years of follow-up.

Fitmore

The Fitmore (ZimmerBiomet) is an uncemented monoblock stem (Fig. 7). It is made of a titanium alloy with a proximal rough titanium, plasma-sprayed, porous coating to promote the bone ingrowth. It was designed to achieve a more physiological proximal load transfer with the main amount of loading force focused on the calcar region.

The Fitmore stem demonstrated a survivorship of 100% with femoral revision for loosening as the endpoint, at a mean follow-up of 1.3 years in 500 hips.[76] The intra-operative peri-prosthetic fracture rate was 0.2%. In the first 100 cases, the authors reported > 2-mm stem subsidence in 34% of the hips and diaphyseal cortical hypertrophy in 29% of the hips.

Radiostereometric analysis

RSA is the gold-standard measure for the assessment of early migration because of its accuracy and predictive value.[77] It requires prospective planning, implantation of tantalum markers and special stereoradiographs.[78] In patients undergoing conventional THA, early implant migration represents the best predictor of mechanical failure and, therefore, it is an important factor impairing the long-term survival of the prosthesis.[79]

Acklin et al[80] conducted a prospective cohort study of 34 patients undergoing THA with Fitmore to measure the stem migration at 3, 6, 12 and 24 months post-operatively. At three months, the mean subsidence was -0.39 mm (95% confidence interval (CI) -0.60 to -0.18) and it was stable at two years, while the mean internal rotation along the longitudinal axis was 1.09° (95% CI 0.52 to 1.66) at two years. Budde et al[81] evaluated the migration of Nanos short-stem implants in 14 patients at 3, 6, 12 and 24 months post-operatively. The highest value of mean subsidence along the proximo-distal axis was –0.22 ± 0.39 mm at three months, while the highest value of mean rotational migration along the longitudinal axis was 0.8° ± 3.2 at 12 months. The mean total migration was 0.46 ± 0.31 mm at 12 months, but the greatest proportion occurred within three months after surgery (0.40 ± 0.34 mm). According to these studies,[80,81] Fitmore and Nanos short stems seem to be affected by an early slight migration and rotation within three months after surgery, followed by a secondary stable fixation.

McCalden et al[82] performed a randomized controlled trial (RCT) comparing the patterns of migration of a short modular stem with metaphyseal fixation (SMF; Smith&Nephew) in 22 patients with those of a standard-length stem with metaphyseal fixation (Synergy, Smith&Nephew) in 21 patients. At 24 months after surgery, there was no statistically significant difference in mean migration between the groups: total migration was 1.09 ± 1.74 mm and 0.73 ± 0.72 mm, respectively. The vast majority of stems in both groups had a total migration < 0.6 mm, subsidence < 0.5 mm and rotation < 1.0°. In the group with SMF, three of them had an early migration > 1.0 mm which then stabilized within six months, and one of them had an early progressive migration requiring revision three years after surgery.

Röhrl et al[27] investigated the migration of CFP in 26 hips followed for two years post-operatively. The stem demonstrated a good early fixation, as shown by the low mean subsidence (0.05 ± 0.06 mm) and the low mean varus-valgus tilting (0.03 ± 0.01). However, the stem reported an early retroversion movement (0.6 ± 0.3), which stabilized within the first year after surgery.

Nieuwenhuijse et al[66] evaluated the migration of CUT in 39 hips followed up to five years after surgery, taking into account mediolateral, craniocaudal and anteroposterior (AP) migration. The median total tip migration was 0.42 mm (0.09 to 9.36) at six weeks and 0.89 mm (0.13 to 6.39) at five years. Although 74% of stems had a migration > 1 mm in the mediolateral or craniocaudal or AP direction, only 10% were considered loose. One of them showed a rapid initial migration without any tendency to stabilize; the remaining three showed continuous excessive migration continuing after two years of follow-up.

Mahmoud et al[83] investigated the migration of Proxima in 28 hips followed for two years after surgery. The mean subsidence and varus tilt were low, such as 0.22 ± 0.28 mm and 1.04 ± 0.81. In all stems, the migration and rotation occurred within three months after surgery and resulted in a secondary stable fixation. No cases of loosening were reported.

Einzel-Bild-Roentgen-Analyse femoral component analysis (EBRA-FCA)

EBRA-FCA is a non-invasive method characterized by the retrospective analysis of routinely taken AP view radiographs. Its sensitivity and specificity for detecting an implant migration of 1 mm are 78% and 100%, respectively.[84] Moreover, some authors demonstrated that an axial subsidence > 1.5 mm measured with the EBRA method at two years from THA with conventional cementless straight-stem is predictive for late aseptic loosening and, therefore, a potential cause of revision of the prosthesis.[85]

Schmidutz et al[86] performed an EBRA-FCA assessment of 80 of the first 100 consecutive hips receiving a METHA available as a monoblock or as a modular implant with cone adapters. After an average follow-up of 2.7 years (2.0 to 4.2), the average subsidence of the stems was 0.7 ± 1.8 mm with no implants requiring revision surgery. The vast majority of the implants (92.5%) were primarily stable with a mean migration of -0.2 ± 0.35 mm. The 5% of the stems showed a secondary stabilization within two months after an initial subsidence. Finally, 2.5% of the stems showed a continuous subsidence. For this reason, the authors concluded that the METHA short stem provides a high degree of stability after two years.

Kutzner et al[87] investigated the migration of metaphyseal-anchoring, calcar-guided short stem (Optimys, Mathys Ltd.) in 202 hips for a two-year follow-up period. The average axial subsidence of the stems was 1.43 ± 1.45 mm with no implants requiring revision surgery. In all stems, the subsidence was pronounced in the first post-operative months followed by secondary stabilization. The authors also demonstrated that age, BMI and different offset versions did not affect the amount of implant migration. In another study including 216 hips undergoing THA with the Optimys stem, Kutzner et al[88] investigated the relationship between varus and valgus positioning and stem stability. The authors divided the hips into five groups according to the mean value of the caput-collum-diaphyseal (CCD) angle (123.3°, 128.0°, 132.4°, 137.5° and 142.5°, respectively). After two years, the axial subsidence and the mean varus/valgus tilt were significantly increased in stems with valgus alignment. However, none of the stems required revision for loosening.

Dual-energy x-ray absorptiometry (DEXA) analysis

Some authors investigated the bone remodelling characteristics of the femur after THA with a METHA stem by using DEXA assessment and adapting Gruen zones (R1 to R7) to the short stem design.[89–92] In all studies including 176 hips with at least one year of follow-up, the bone mineral density (BMD) significantly increased in the lateral regions (R2 and R3) and significantly decreased in the proximal regions (R1 and R7). On the other hand, changes in distal (R4), distal-medial (zone 5) and lesser trochanter (R6) regions were less relevant and reliable across the analysed studies. These results suggest a good osseointegration of the stem, but the load transfer seems to occur particularly in the lateral and distal-medial regions, favouring proximal stress shielding and bone atrophy in the great trochanter and calcar regions.

Zeh et al[93] investigated the bone remodelling with the Nanos stem in 25 hips up to 12 months post-operatively. The DEXA scan demonstrated a significant increase in BMD in R6 according to Gruen (12%) and a significant decrease in R1 (-15%), R2 (-5%) and R7 (-12%), suggesting a load transfer in the medial-distal part of the femoral metaphysis. In a previous study including 36 hips, Götze et al[94] reported a decrease of BMD in R1 (-6.4%) and R7 (-7.2%) but demonstrated an increase of BMD in R2 (9.7%) due to bone ingrowth in the lateral-distal region at one year follow-up. The authors concluded that a proper proximal load transfer could not be achieved with this stem, resulting in proximal stress shielding.

Logroscino et al[95] compared the bone remodelling around the Nanos stem (12 hips) with that around the Proxima stem (19 hips), reporting an increase of periprosthetic BMD with both implants. In the Nanos group, BMD values were significantly higher in the R3 and R4 zones, whereas there were no differences in the R1, R2 and R5 zones. No cases of stress shielding were reported in either group. On the other hand, Brinkmann et al[96] performed a DEXA prospective RCT comparing the Nanos stem (26 hips) with METHA stem (24 hips). At 12 months, the DEXA scans showed a decrease of BMD in the R1 zone for both METHA and Nanos stems (-8% and -14%, respectively) and an increase of BMD in R6 zone (9%) for the METHA stem.

Gasbarra et al[97] evaluated bone remodelling around the Fitmore stem in 33 hips. At one year follow-up, a greater BMD increase was reported in R7 (8.3%). Positive changes of BMD values were also reported in the R1, R3 and R5 zones (1.7%, 4.1% and 2.1%, respectively), whereas negative changes were reported in the R2 and R4 zones (-4.8% and -1.8%, respectively). These findings suggest a significant load transfer in the medial proximal region of the femur, preventing its bone resorption as reported with other short stems. Moreover, Freitag et al[98] compared the bone remodelling around the Fitmore stem (57 hips) with that around a cementless straight stem (CLS, ZimmerBiomet) (81 hips) at one year follow-up. The authors demonstrated a more significant proximal load transfer with the short stem, as shown by the most pronounced peri-prosthetic BMD changes in the proximal medial region R7 (-17.2% *versus* -16.7%). Finally, the BMD reduction in R6 zone was less relevant with the short stem (-4.7% *versus* -10.8%).

Chen et al[99] performed a DEXA study including 29 hips undergoing THA with the Mayo stem, with an average follow-up of 5.7 years (1 to 12). Compared with the contralateral side, the greater decrease in the BMD values was reported in the proximal zones (-14.4% in R1, -14.4% in R6 and -17.9% in R7). On the other hand, a significant increase in BMD values was demonstrated in the lateral side zones (R2 9.2% in R2 and 20.9% in R3).

Lazarinis et al[100] performed a prospective cohort study enrolling 30 hips receiving the CFP stem. The DEXA analysis was performed in 27 hips and showed a significant decrease of BMD values in R7 (-31%), R6 (-19%) and R2 (-13%) zones at one year follow-up. Two years after surgery, the bone loss in these regions did not recover, whereas the less relevant bone loss in the R1, R3 and R5 zones partially recovered. According to these results, the CFP stem seems to transfer loads distally leading to proximal peri-prosthetic bone loss.

Finally, Salemyr et al[101] performed a RCT comparing Proxima (26 hips) with a conventional tapered titanium stem (Bi-metric, Biomet) (25 hips) in terms of changes in peri-prosthetic BMD in Gruen zones 1 and 7, two years after surgery. The authors concluded that the ultra-short stem provided lower peri-prosthetic bone loss with a mean difference of 18% (95% CI -27 to -10) in R1 and 5% (95% CI -12 to -3) in R7.

Conclusions

Conservative stems included in this review showed a survivorship in the range of 96% to 100% in the short term, despite the fact that they can be associated with complications such as stem malalignment, incorrect stem sizing and intra-operative fracture. The vast majority of stems demonstrated a good osseointegration, but some prostheses transferred loads particularly to the lateral and distal-medial regions favouring proximal stress shielding and bone atrophy in the great trochanter and calcar regions. Finally, some conservative stems were affected by an early slight migration and rotation within the first months after surgery, followed by a secondary stable fixation.

Although the clinical and radiological outcomes of some conservative stems are promising, their use in clinical practice needs careful indications and proper surgical technique. Because no studies with long-term follow-up are currently available in the literature, comparative studies with a longer follow-up are strongly recommended to demonstrate that conservative stems can provide long-term results comparable to well-established conventional uncemented stems.

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