Short Femoral Stems for Primary Total Hip Arthroplasty in Young Patients: Clinical and Biomechanical Outcomes*

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ABSTRACT

Total hip arthroplasty is an effective surgery to treat osteoarthritis. Given the rising demand for a higher quality of life, this procedure is being performed on increasingly younger patients. However, a longer life expectancy is also tied to a higher demand for multiple revision surgeries for the same patient. This poses technical challenges due to bone loss. There is a growing need to identify durable and highly functional implants that are suitable for future revision. Although cemented femoral stems were the main option in the past, uncemented femoral stems have demonstrated long-term fixation and excellent results. However, some issues related to fixation can still be improved. Short femoral stems have been developed to address some of these challenges while maintaining the good results obtained with conventional stems. This study analyzes the experience after 10 years of using short femoral stems in hip surgeries on young patients. Biomechanical outcomes and femoral bone preservation are compared, postoperative outcomes regarding return to sports are reported, and complications related to their use are evaluated. Short stems have multiple advantages when used in primary hip surgery.. The indication for this type of implant is justified in young and active patients, to reproduce the results of conventional implants with less bone consumption and the possibility of future revision.

Keywords: total hip arthroplasty; short stem; hip osteoarthritis.
Level of Evidence: IV

Vástagos femorales cortos para el reemplazo total de cadera primario en pacientes jóvenes. Resultados clínicos y biomecánicos*

RESUMEN

La artroplastia total de cadera es una cirugía eficaz para tratar la artrosis. Con el aumento de la necesidad de una mejor calidad de vida, este procedimiento se está realizando en pacientes más jóvenes. Pero, con la mayor expectativa de vida, también crece la demanda de múltiples cirugías de revisión para el mismo paciente. Esto plantea desafíos técnicos debido a la pérdida de hueso. Existe una necesidad creciente de identificar implantes duraderos y altamente funcionales que sean adecuados para la revisión futura. Aunque los vástagos femorales cementados eran la opción principal en el pasado, los vástagos femorales no cementados han logrado una fijación a largo plazo y excelentes resultados. Sin embargo, aún se pueden mejorar algunos problemas relacionados con la fijación. Los vástagos femorales cortos han sido desarrollados para abordar algunos de estos desafíos, mientras se mantienen los buenos resultados obtenidos con los vástagos convencionales. En este artículo, se analiza la experiencia tras 10 años de uso de vástagos femorales cortos en cirugías de cadera en pacientes jóvenes. Se comparan los resultados biomecánicos y la preservación ósea femoral, se reportan los resultados posoperatorios en relación con el regreso al deporte, y se evalúan las complicaciones relacionadas con su uso. El empleo de vástagos cortos en cirugía primaria de cadera brinda múltiples ventajas. La indicación de este tipo de implante está justificada en pacientes jóvenes y activos, con el objetivo de reproducir los resultados de los implantes convencionales con un menor consumo de hueso y la posibilidad de una revisión futura.

Palabras clave: Artroplastia total de cadera; tallo corto; artrosis de cadera.
Nivel de Evidencia: IV

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INTRODUCTION

Total hip arthroplasty (THA) is a clinically, functionally, and radiologically successful procedure for the treatment of degenerative hip disease.[1,2] Over the last three decades, the number of patients undergoing THA has increased significantly, as has life expectancy and activity level,[3] implying an increase in revision surgery in the future.[4] This has sparked interest in bone-sparing prosthesis designs that enable a minimally invasive, tissue-sparing surgical approach in order to facilitate future THA revisions without compromising surgical outcomes or primary surgery survival.

Cementless THA has become the standard fixation option in the United States, Canada, and many European countries, and is used in more than 90% of all primary THAs.[5,6] However, despite the success of these components and the scope of their indication, a number of particular challenges for cementless fixation technologies in younger patients have emerged. These challenges include:

1. Preservation of the proximal femoral bone stock.
2. Potential need for an effective revision of the femoral component.
3. Femoral anatomomorphological mismatch due to proximal-distal mismatch.
4. Ability to insert implants safely and reproducibly.

Short stem cementless femoral implants have been developed to address some of these issues, as long as they do not hinder the current level of success achieved by conventional length cementless implants. Wear caused by metal and polyethylene microparticle debris, early and late periprosthetic fracture, aseptic loosening, and dysfunction-induced bone loss of the proximal femur all increase the risk of revision THA in young patients. Some of these complications are caused by nonphysiological femoral stresses. Responding to the demands of an increasingly young and active patient population, recent advances in hip arthroplasty aim to minimize tissue damage and spare bone without compromising implant stability. This has resulted in the introduction of innovative femoral bone-preserving implants, such as short-stem THAs,[7] with the aim of preserving bone for future revisions.

DEFINITION AND CHARACTERISTICS OF SHORT STEMS

THA success is based on both initial rotational and axial stability (fixation by interference),[8] which are responsible for promoting long-term implant fixation (definitive fixation). There are various types of uncemented fixation that influence the femoral preparation. On the one hand, there are stems that are exclusively metaphyseal (they are ‘reamed’ only in their femoral preparation), wedge-shaped, and typically have a proximal porous titanium cover (coated or uncoated), while their distal surface is typically rough (in very few cases, the distal surface is polished). Second, there are stems with anatomical fixation (they are ‘scaled and reamed’ for femoral preparation), and they typically have a completely porous surface to occupy the entire metaphyseal and diaphyseal cavity in both anteroposterior and lateral radiographs. Finally, there are stems with distal fixation, which are solely diaphyseal (they are only ‘reamed’ for their femoral preparation). They are commonly used in primary hip surgeries for dysplasia to ‘bridge’ very anteverse femoral necks or metaphyses with significant extra-articular deformity. The metaphyseal wedge-shaped conventional-length stems (i.e., those that are only scraped for placement), which have been associated with less long-term osteolysis of the proximal femur, have historically been the modern implants that best promote physiological weight-bearing.

All stems designed to be less invasive than conventional uncemented stems are commonly referred to as “short stems” (except for surface replacements which, despite preserving bone stock, do not have a stem *per se*). Short-stem implants have been defined as those measuring <120 mm in length, which normally coincides with the metaphyseal-shaft junction. According to a recent study, reducing the stem length to less than 105 mm does not reduce the interference stability of cementless fixation implants.[9] However, this term is misleading, because it refers to a heterogeneous group of stems that differ in terms of design, biomechanics, and fixation principles. For this reason, various classification systems have been developed taking into account characteristics such as stem length, weight-bearing location, osteotomy level for neck resection, and implant fixation principles.[10,11] McTighe et al.[10] have proposed a classification based on the three main types of short-stem implant fixation:

1. Stabilized metaphyseal (standard neck resection).

2. Stabilized neck (preservation of the femoral neck).

3. Stabilized head (surface prosthesis).

Standard neck resection short-stem implants can be further classified into anatomical and wedge-fixation implants. These implants also tend to be shortened versions of conventional cementless implants. On the other hand, the implants that preserve the femoral neck adapt to the anteversion of the remaining femoral neck depending on the level of the osteotomy performed.[12]

In 2014, Khanuja et al.[13] tried to answer this question. Given the existence of various types of proximal fixation, the authors classify short stems into four large groups, each of which contains subgroups: type 1A, prosthesis with exclusive support in the trapezoidal section neck; type 1B, exclusive neck support prosthesis with rounded geometry and ridges for rotational stability; type 1C, exclusive neck support prosthesis with ridged geometry for rotational stability; type 2A, calcar-loading prosthesis with trapezoidal section and wedge design; type 2B, calcar-loading prosthesis with rounded section and partial femoral neck preservation; type 2C, neck preservation stem with fixation in the lateral metaphyseal cortex; type 2D, or screw-plate design that compresses the calcar against the outer metaphyseal cortex; type 3, stems with lateral trochanteric extension, and type 4, stem of conventional design but shorter in length, seeking only metaphyseal fixation. (Figure 1).

Periprosthetic bone remodeling of the proximal femur is an important factor in achieving long-term stability of an implant. This depends on its geometry and the femoral canal, and on the ratio of load transfers from the implant to the bone. The stability of these shorter stems depends on their metaphyseal fixation, which is a requirement for optimal proximal load transfer.[14,15] Biomechanical studies have shown that the optimization of proximal load transfer has a positive impact on the preservation of bone stock. Chen et al.[16] analyzed the bone stock in patients who had undergone THA with a short Mayo stem (Zimmer International, Warsaw, IN, USA). Through dual-energy X-ray absorptiometry (DEXA), a mean bone loss of only 3.3% has been demonstrated in patients with short stems, compared to the literature standard of 20% with conventional implants.[17] However, it should be noted that a randomized controlled study[18] compared bone remodeling between a shortened stem and a conventional-length stem using dual-energy X-ray absorptiometry region-free analysis (DEXA-RFA). The authors identified a consumption of periprosthetic bone stock in the calcar, and the lateral and proximal femoral aspect in both groups ($p < 0.05$). In other words, femoral bone remodeling appears to be multifactorial, conditioned by the anatomy of the proximal femur, previous osteopenia, intraoperative femoral preparation, and the degree of interference fixation achieved in the primary surgery. However, it is not a minor fact that the geometry of the stem and its length (short vs. conventional) could have a significant long-term influence on bone remodeling and this remains to be clarified with new randomized studies; hence the current interest in short stems.

Short neck-preserving stems are a promising alternative to conventional uncemented stems. This is mainly due to their bone-preserving nature that would allow for easier revision surgery, as well as biomechanical advantages such as a potential improvement in axial load transmission. On the other hand, osseointegration could be more favorable due to the reduction of cyclical movement after implantation. The effects of stress shielding are reduced by a higher physiological load on the femur due to the lower flexural stiffness of the new stem. In this sense, it has been proposed that the use of a short femoral stem could have various advantages:

1. Preservation of bone stock and soft tissues, in the greater trochanteric and subtrochanteric regions, at the time of implantation for future revisions.[19]

2. Reduction of stress shielding, caused by the resorption of the metaphyseal bone and the diaphyseal cortical hypertrophy.[20]

3. Decreased stress concentration at the tip of the stem, which has been shown in a traditional component to be the cause of thigh pain.[20.21]

4. The tension band effect of the IT band provides compressive forces both medially and laterally on the proximal femur.[22] The lateral cortex provides strong support as a second column of compression.[22,23]

5. The transfer of load to the metaphysis from a superior to an inferior direction in a physiological way.[22-24]

6. Versatility in revision surgery due to the minimally invasive approach, less soft tissue damage, and intact bone stock below the lesser trochanter.[22,23]

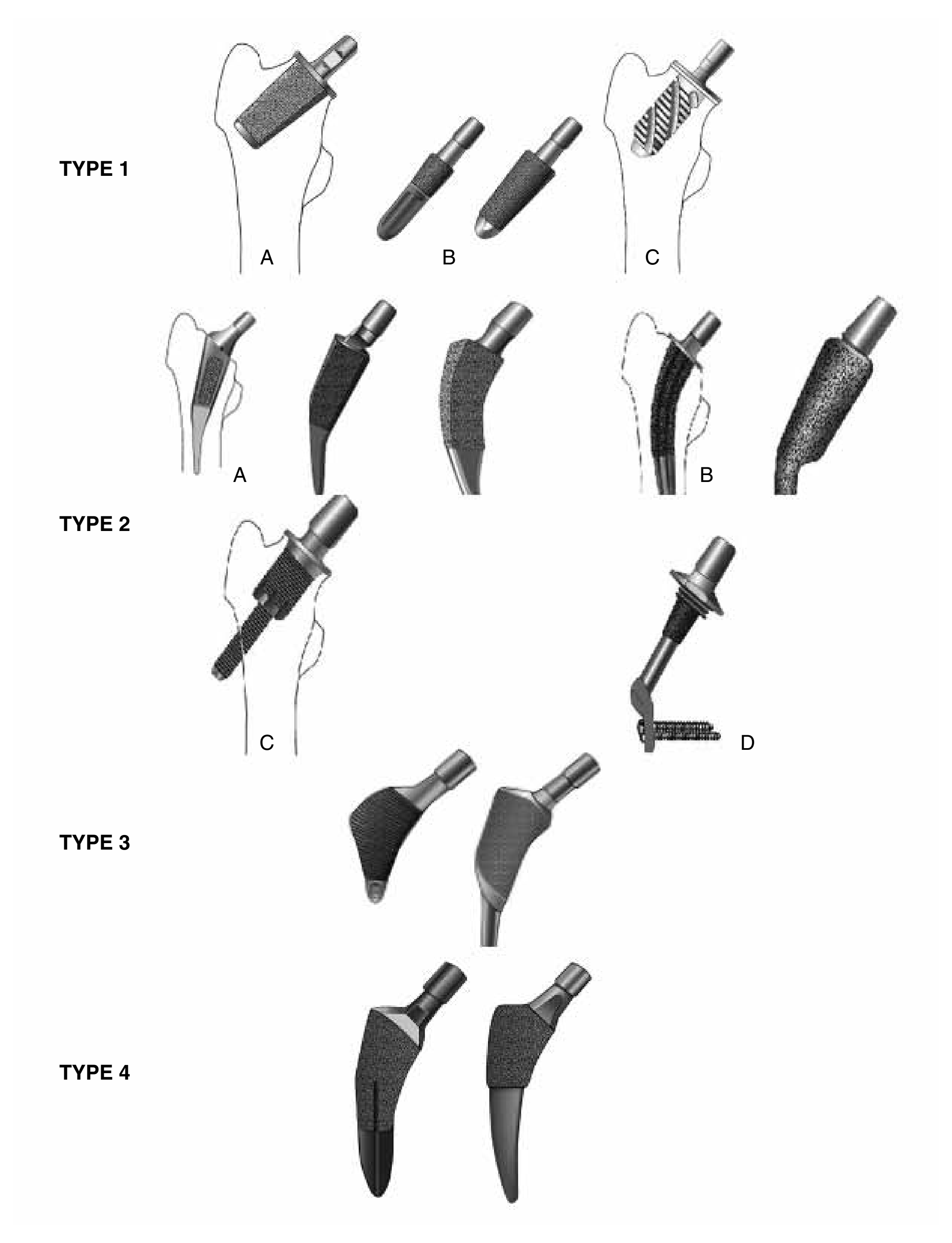

Figure 1. Classification of short stems. Type 1A, prosthesis with exclusive neck support, trapezoidal section; type 1B, prosthesis with exclusive neck support, with rounded geometry and grooves for rotational stability; type 1C, prosthesis with exclusive neck support, with ridged geometry for rotational stability; type 2A, prosthesis with calcar support, with trapezoidal section and wedge design; type 2B,prosthesis with calcar support, with a rounded section and preservation of the femoral neck; type 2C, neck preservation stem with fixation in the lateral metaphyseal cortex; type 2D, or screw-plate design that compresses the calcar against the outer metaphyseal cortex; type 3, stem with lateral trochanteric expansion; type 4, stem of conventional design, but shortened in length, seeking only metaphyseal fixation in the proximal femur.

From the demographic point of view, its implantation in young patients (≤55 years) is preferable, although in a lower proportion (15%), they can be used in patients between 55 and 60 years of age who practice sports recreationally (Figure 2A and B). It is a requirement that this group of patients have adequate metaphyseal bone stock together with an intact femoral neck, a morphologically normal calcar and a sufficient distal lateral femoral cortex to achieve correct fixation and anatomical restoration.

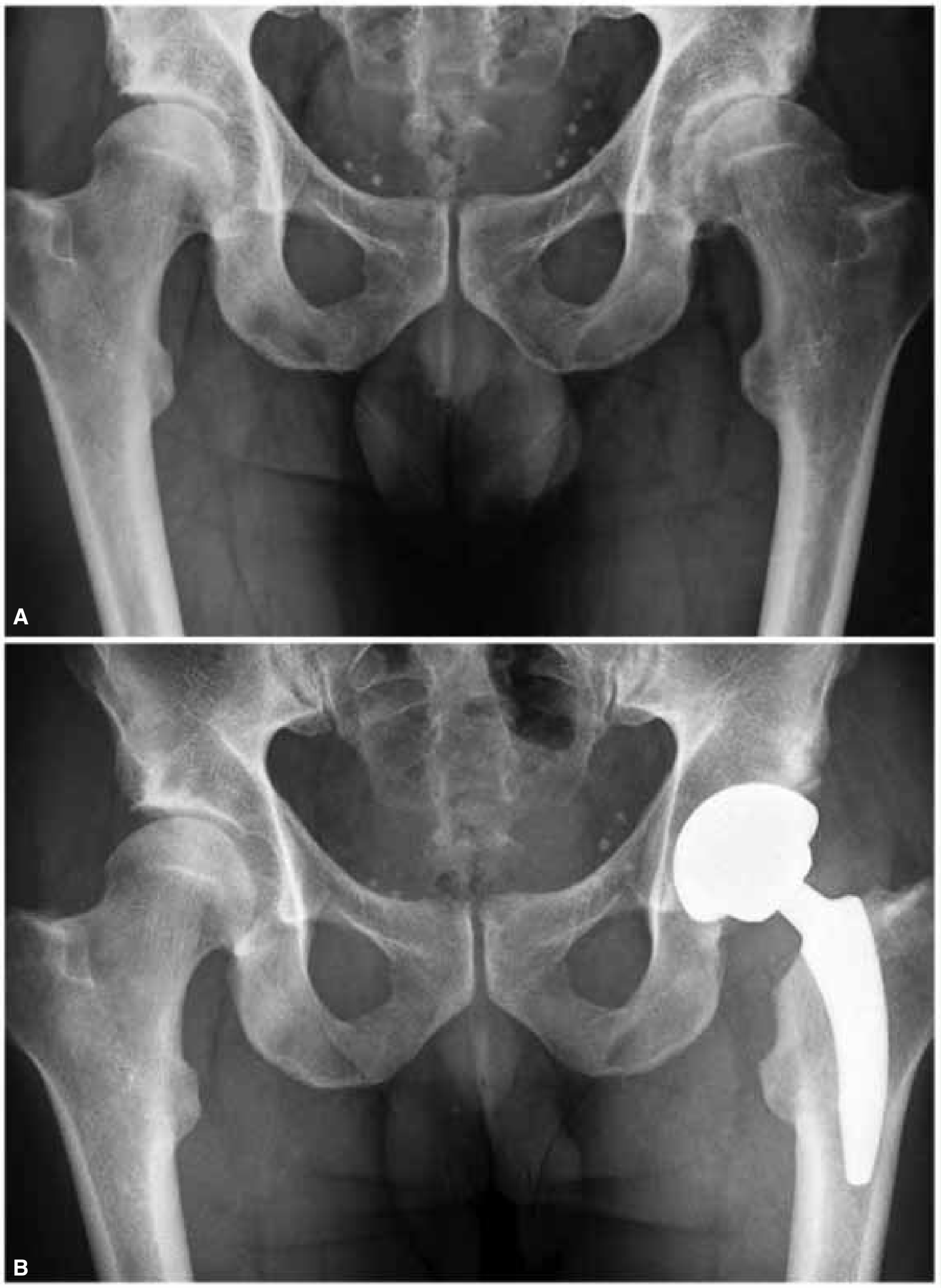

Figure 2. A. Preoperative anteroposterior radiograph of both hips. 52-year-old patient with primary osteoarthritis of the left hip. **B.** Anteroposterior radiograph of both hips. A total left hip replacement with a MiniHip^{TM} stem, 4 years after surgery.

Contraindications to the use of short stems in primary hip surgery include age >60 years, severe metaphyseal translational deformity of the femur, severe osteoporosis, or pathologies in which there is a significant mismatch between the size of the neck and the femoral metaphysis, for example, in a multiple osteochondromatosis (Figure 3).

Figure 3. Anteroposterior radiograph of both hips. Bilateral aggressive multiple osteochondromatosis, contraindicating implantation of a short femoral stem.

During surgery, it must be confirmed that the bone quality is suitable for implantation and that the femoral neck area is strong enough to support the load transmission of a short stem. For this reason, if this requirement is not met, the authors always recommend having an uncemented stem of conventional length.

Our interest in short stems began in 2010, when the results of resurfacing arthroplasty began to be poor due to the release of metal particles derived from the friction surface, causing adverse reactions such as metallosis, pseudotumors, and short-term failure, with complications associated with revision surgeries in these patients.[25] After a detailed analysis of the short stems available in our country, we decided on a coated system similar to the one we used for conventional uncemented stems, with excellent outcomes after 20 years of follow-up.[26] The hydroxyapatite, as well as the loading surface, were exactly the same as what we were using at the time. This chosen design was approved by the *Food and Drug Administration* and quickly became popular in Germany and the United Kingdom, and it was not only shorter than a conventional uncemented stem, but it also preserved part of the femoral neck, according to various publications.[25,27] There are nine size options with a 130° cervicometaphyseal angle, and their longitudinal serrations are designed to resist torsional forces.

Objective:

The objective of this work was to analyze the following points after 10 years of experience with the use of short femoral stems in hip surgery in young patients:

1. Femoral bone preservation.
2. Biomechanical reconstruction.
3. Medium-term outcomes of the first 100 cases.
4. Comparative functional outcomes in a young athlete population.
5. Medium-term comparison with uncemented stems of conventional length.
6. Comparative rate of intraoperative complications between two designs that partially preserve the femoral neck.
7. Medium-term outcomes in patients with developmental dysplasia of the hip.
8. Complex situations: medium-term outcomes in proximal femoral deformities.

1. FEMORAL BONE PRESERVATION

Material and methods

The first 50 short stems (MiniHip™, Corin, Cirencester, United Kingdom) were analyzed in a comparative retrospective study with the objective of radiographically determining the preservation of femoral bone stock when a short stem for cervicometaphyseal fixation was used.[27] Anteroposterior radiographs were used to assess the level of cervical resection and the length of the stem. These were compared with filmstrips from a conventional metaphyseal-shaft fixation stem (MetaFix™, Corin, Cirencester, UK).

The average age of the patients was 46.7 years (range 21-62); 38 patients were male and 12 were female. The main diagnoses were degenerative osteoarthritis (42 cases), developmental dysplasia of the hip (5 cases), osteonecrosis (2 cases) and idiopathic chondrolysis (1 case). All implants were placed by the same surgeon through a posterolateral approach under spinal anesthesia.

The preoperative planning of the short stems was performed according to the method described by Salvati et al.,[28] and was carried out by a surgeon with more than 10 years of experience in the use of this method. Postoperative digital radiographs of patients in whom a cervicometaphyseal fixation stem was implanted were analyzed by two independent observers, overlaying films from a hydroxyapatite-coated metaphyseal fixation stem (MetaFix™). The length of the conventional stem and the cut level of the femoral neck necessary to implant this stem were drawn. The difference in longitudinal bone preservation between the two implants was then quantified at the femoral neck and diaphyseal levels, with the total resulting from the sum of both measurements and implant lengths (Figure 4A and B).

Results

The short cervicometaphyseal fixation stems radiographically preserved an average of 77 mm when compared to those of conventional length. The neck cut on the conventional stems was between 3 and 15 mm more distal than with the short stems. (average 10mm). Conventional implants occupied 66 mm more shaft (range 41-81) than short stems ($p < 0.001$). The average length of the implanted short stems was 82 mm (range 68-102). The average length of conventional metaphyseal-shaft fixation stems was 142 mm (range 132-151) ($p < 0.001$) (Table 1). According to these results, the short stems allowed radiographic preservation of 42% of bone length compared with the metaphyseal-diaphyseal fixation stems (Figure 4 C).

2. BIOMECHANICAL RECONSTRUCTION

Material and methods

A retrospective descriptive study[29] was carried out that included 124 patients with a mean age of 52 years (range 26-65). Three groups of patients were analyzed: the first group consisted of 36 patients who were implanted with a MiniHip™ short-stem prosthesis, the second group included 46 patients with a conventional cementless Corail® total hip prosthesis (DePuy-Synthes , Warsaw, IN, USA), and the third included 42 patients treated with a resurfacing prosthesis (Durom, Zimmer, Warwae, IN, USA).

Figure 4. **A.** Measurement procedure with a postoperative anteroposterior radiograph of the hip. The neck cut level and the length of the implant that would have been placed in the case of using a metaphyseal-diaphyseal fixation stem are drawn. **B.** The two measured implants are shown: the cervicometaphyseal fixation stem (on the right) and the metaphyseal-diaphyseal fixation stem (on the left). **C.** Patient with a cervicodiaphyseal fixation stem in the right hip and a metaphysodiaphyseal fixation stem in the left hip. Note the difference in length at the level of the neck cut and in the invasion of the femoral canal.

Table 1. Comparative analysis of femoral preservation between a short stem and a conventional length stem

Case	Prox*	Distal	Sum	MiniHip™	MetaFix™	p
Average	10.04	66.44	77	82.72	141.88	<0.001
Highest	15	81	94	102	151	<0.001
Lowest	3	41	47	68	132	<0.001

*Distance measured at the femoral neck.
MiniHip™ = MiniHip TM stem length; MetaFix™ = MetaFix™ stem length.
Nally FJ, Rossi LA, Diaz F, Stagnaro J, Isodoro Slullitel PA, Buttaro MA. Which prosthetic system restores hip biomechanics more effectively? Comparison among three systems. *Current Orthopaedic Practice* 2015;26:382-6.

After the Institutional Ethics Committee approval, the study included patients <65 years of age who had osteoarthritis of the hip and a contralateral healthy or early osteoarthritis hip (Tönnis 0 or 1),[30] which was used as a control for biomechanical parameters. All surgeries were performed through a posterolateral approach. Simultaneous bilateral arthroplasties were excluded, as well as fractures or other diagnoses or any surgical history of the affected hip.

Radiographic measurements were performed by three independent observers using a digital imaging system (RAIMViewer, USA) previously calibrated to the size of the femoral head implant. The three observers analyzed three different subgroups of patients. The same observer measured the postoperative period and the healthy contralateral hip to avoid interobserver bias.

Lower limb length discrepancy was measured on radiographs using the distal endpoint of the teardrop sign and the lesser trochanter as references. Once the discrepancy value was obtained, the discrepancy of the center of rotation was subtracted to exclude the acetabular factor and obtain discrepancy data only for the femur. Femoral offset was evaluated by measuring the distance between the axis of the femoral shaft and the center of rotation of the femoral head.

The horizontal center of rotation was defined as the distance between the center of hip rotation and the center of the distal end of the teardrop sign. The vertical center of rotation was measured from the center of rotation of the femoral head to a line passing through the two vertices of the distal end of the teardrop sign.

Acetabular tilt was calculated using the angle between a line passing through the two vertices of the distal end of the teardrop sign and the axis of the acetabular component. The Lewinnek[31] method was used to assess acetabular anteversion (arcsine of the width of the ellipse over the external diameter of the implant). It was determined if the position of the cup was within the Lewinnek safe zone (40 ± 10° of inclination and 15 ± 10° of anteversion).

Results

Horizontal center of rotation

The average discrepancies in the horizontal center of rotation were not statistically significant when comparing the three prostheses (p = 0.275). The horizontal center of rotation was slightly medialized in the short stem group (-0.09 mm; p = 0.189) and in the conventional stem group (-0.58; p = 0.39), while it was slightly lateralized in the group with resurfacing prosthesis (0.51 mm; p = 0.45). In 16 cases with a short stem (44.4%), 29 cases with a conventional stem (63%), and 28 cases with a surface prosthesis (66.6%), the horizontal center of rotation was restored within ± 3 mm (p = 0.85).

Vertical center of rotation

The differences in the vertical center of rotation between the three groups were not statistically significant (p = 0.425). The vertical center of rotation was more proximal with the three prostheses: 1.75 mm (p = 0.021) in the short stem group, 1.32 mm (p = 0.021) in the conventional stem group, and 2.34 mm (p = 0.001) in the resurfacing group. In 17 short-stem cases (52.7%), 34 conventional-stem cases (73.9%), and 23 resurfacing cases (54.7%), the center of vertical rotation was recovered by 3 mm (p = 0.08).

Lower limb length discrepancy

The average leg length discrepancy was 1.19 mm in the short stem group; 2.31 mm in the group with a conventional stem and 2.11 mm in the group with a resurfacing prosthesis (p <0.001). In 67.3% of those with surface prosthesis, the restoration remained in a range of less than ± 5 mm (p = 0.103). Femoral length discrepancy averaged -0.87 mm in the short stem group, 0.34 mm in the conventional stem group, and -4.44 mm in the resurfacing group (p = 0.003).

Femoral lateralization

The mean femoral offset difference between the three groups was statistically significant (p = 0.0001). When compared to the contralateral healthy side, mean postoperative lateral offset increased by 3.51 mm in the short stem group (p = 0.001) and 1.71 mm in the conventional stem group (p = 0.081), while it was reduced 3.95 mm in the resurfacing group (p = 0.001). Femoral displacement was within ± 5 mm in 23 cases of short stem (63.8%); 33 cases of conventional stem (71.7%) and 27 cases of surface prosthesis (64.2%) (p = 0.683) (Table 2).

Table 2. Biomechanical parameters of the different prostheses compared with those of the normal contralateral hip

	SS (p)	CLS (p)	SP (p)
Horizontal center of rotation	-0.9 (0.189)	-0.58 (0.392)	0.51 (0.45)
Vertical center of rotation	1.75 (0.021)	1.32 (0.021)	2.34 (0.001)
Femoral lateralization	3.51 (0.001)	1.71 (0.081)	-3.95 (0.001)
Length discrepancy up to ± 5 mm	94.4%	86.9%	67.3%
Safe zone	88.9%	93.5%	83.3%

SS = short stem; CLS = conventional length stem; SP = surface prosthesis.
Nally FJ, Rossi LA, Diaz F, Stagnaro J, Isodoro Slullitel PA, Buttaro MA. Which prosthetic system restores hip biomechanics more effectively? Comparison among three systems. *Current Orthopaedic Practice* 2015;26:382-6.

3. MEDIUM-TERM RESULTS OF THE FIRST 100 CASES

Material and methods

In a retrospective study,[32] the first 84 patients (100 hips) treated with a THA with a type 2B short stem were prospectively analyzed.[13,33] The surgeon's learning curve was included in these cases. Sixteen patients were operated sequentially, on both sides, on the same day. The average age was 47 years (range 17-58). In this series, the indications for a short stem were: young patients with a maximum age of 55 years (85 cases) and patients between 56 and 60 years of age who had practiced impact sports in the past (15 cases). The sports or activities defined as having an impact were: running, soccer, taekwondo, *squash*, and aerobic gymnastics training. The average body mass index (BMI) of the group was 27 kg/m^2 (range 22-37). The primary diagnosis was primary osteoarthritis (82 cases), developmental dysplasia (6 cases), osteonecrosis (8 cases), idiopathic chondrolysis (2 cases), sequelae of Perthes disease (1 case) and pigmented villonodular synovitis (1 case).

Surgical technique

Preoperative planning is a fundamental and mandatory step that can be performed according to analog or conventional methods.[34] Depending on the surgical technique, the cut of the femoral neck is precisely planned to avoid excessive elongation of the operated leg and to calculate the lateralization of the femur. In cases with increased lateralization, a more vertical neck cut is performed and, in cases of decreased lateralization, a more horizontal neck cut, as described by Teoh et al.[35] The entry point on the femur is calculated 4 mm lateral to the center of the femoral neck. In order to avoid cortical perforation, a step can be added to the original surgical technique using a curved vascular clamp in the direction of the femoral canal. After confirming the correct location of the starter instrument in the intramedullary canal, the first starter rasp is placed. The proximal femoral bone is then compacted with rasps of progressive size until rotational stability and lateral cortical contact are achieved.

Results

Stem survival free of aseptic failure was 99% (95%CI 93.1-99.8%) at a mean follow-up of 42 months (range 24-64) and 98% when infection was included. No patient was lost to follow-up. The main complication occurred in case 6 (listed in chronological order of inclusion in the study according to the date of surgery): a perforation of the lateral cortex (Figure 5A) that was treated the same day, during surgery, with conversion of the short stem to one of conventional length with metaphyseal shaft fixation coated with hydroxyapatite (Figure 5B). Likewise, three incomplete intraoperative calcar fractures (3%) were recorded, of which only one required wire cerclage and partial offloading during the first 30 postoperative days.

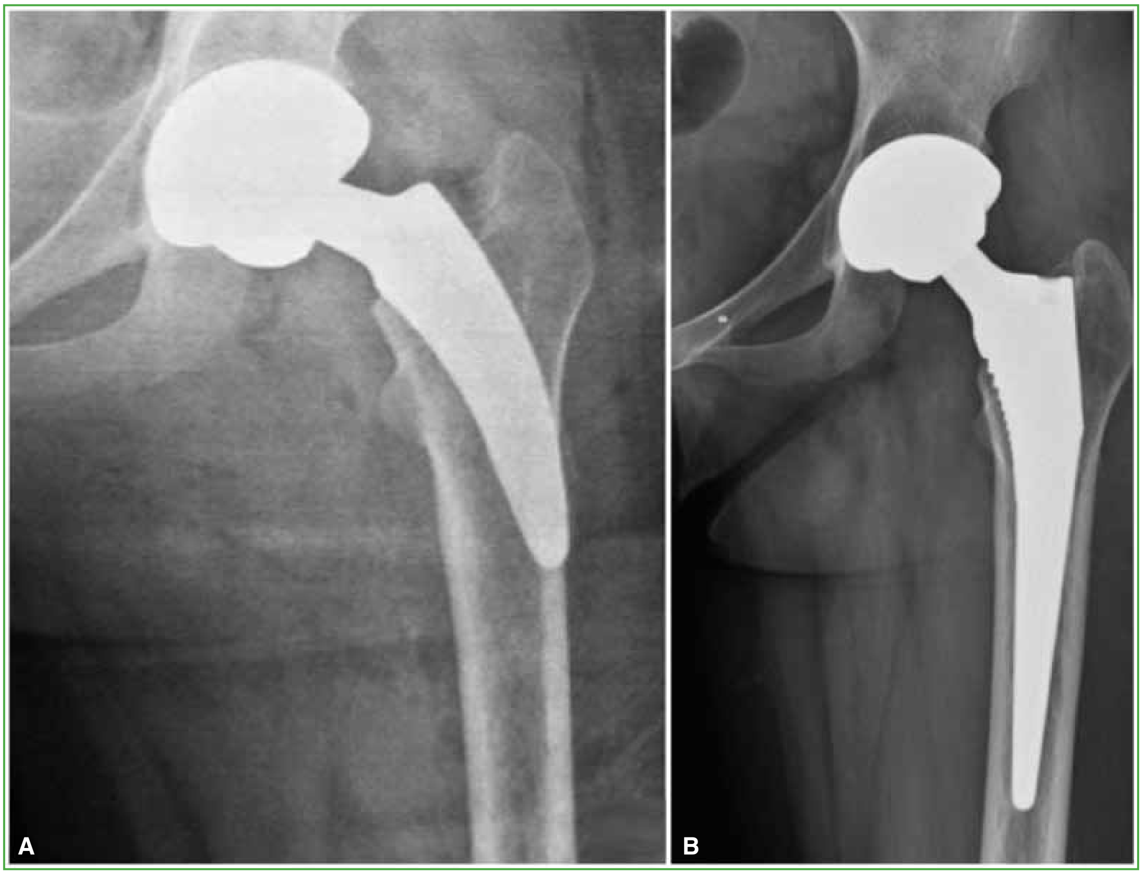

Figure 5. **A.** Anteroposterior radiograph of the left hip in the immediate postoperative period. A 21-year-old patient with idiopathic chondrolysis presented with cortical perforation after bilateral sequential total hip replacement, which was treated with a conventional uncemented stem revision. **B.** Anteroposterior radiograph of both hips 5 years after the revision. The modified Harris score was 95 for each hip.

There was one case of 4 mm subsidence that was stabilized 45 days after the operation and weight-bearing, with no need for additional surgical treatment due to the absence of symptoms.

There were no cases of thigh pain or dislocations. The mean Harris Functional Score (HHS) improved significantly from 55 before surgery to 96 (range 82-100) at the last follow-up ($p < 0.05$). At the last control, 24 patients ran more than 5 km/week, 18 swam 1 or 2 times/week, 12 of them rode a bicycle for more than 2 hours/week, eight played unrestricted golf, six played non-competitive soccer, six practiced martial arts, two of them played basketball and one took up squash. The average weekly sports activity was 6 hours, and 20 patients practiced more than one sport discipline in the last follow-up. The return to sports activity occurred, on average, at 4.4 months (range 3-7).

In all cases, bone incorporation was verified according to the Engh classification.[36]

No stem showed radiolucent lines. The average limb discrepancy was 1.7 mm (range -4.7 to +7). Mean femoral lateralization increased 4.6 mm (range 4 to +7). Six patients had bone remodeling of the femoral neck and three, hypertrophy of the lateral cortex. One suffered a deep acute infection that was successfully treated with debridement, component retention, and antibiotics.

4. COMPARATIVE FUNCTIONAL OUTCOMES IN A YOUNG SPORTS POPULATION

Material and methods

55 patients operated on by the same surgical team were evaluated to describe and quantify the type and intensity of physical activity performed in young patients undergoing resurfacing arthroplasty and those receiving a short cervicometaphyseal fixation stem. This was a comparative study[37] with two temporally associated cohort groups, given the change in the indication in relation to the complications reported with the metal-on-metal friction pair. A comparison was made between the last 31 resurfacing prostheses and the first 31 short-stem prostheses.

In the first group of patients, 31 consecutive resurfacing prostheses (Durom) were implanted, one of them bilateral, and in the second group, 31 consecutive cervicometaphyseal fixation prostheses were implanted, six of them bilateral. The mean age for resurfacing prostheses was 44.6 years (range 34-57) and 51.5 years (range 36-66) for the cervicometaphyseal fixation prosthesis group. All patients were active with advanced primary hip osteoarthritis.

All were operated under spinal anesthesia in a laminar flow operating room through a posterolateral approach. The rehabilitation protocol included early range of motion exercises at 24 hours with full weight-bearing according to pain tolerance. For the first three weeks, they used two Canadian canes and then a walking cane for one to two more weeks according to progress.

A descriptive study was carried out using the score from the University of Los Angeles in California (UCLA), determining the physical activity achieved (type and number of weekly hours) at the end of the follow-up, degree of personal satisfaction during sports practice through a visual analog scale and the need for analgesics before and after physical activity.

Results

The median duration of follow-up was 24 months (range 12-66). The guidelines given to the patients were consistent, allowing them to resume normal activities six months after surgery. Contact sports activity was recorded in 15 patients with surface prostheses and 10 patients with short-stem prostheses. Soccer and basketball were the most common sports, and cycling, a non-contact sport, was the best tolerated, and high performance was achieved in the series.

The mean UCLA score was 9.5 for the resurfacing group and 8.5 for the metaphyseal fixation group. The degree of personal satisfaction corresponded to the results obtained in the UCLA score. Both groups did, on average, 6 weekly hours of physical activity. The average time from surgery to physical activity for the surface prosthesis group was 6.3 months versus 4.4 months for the short-stem prostheses ($p = 0.0031$).

In this series of patients, both implants allowed contact physical activity to be carried out with a comparable regularity in both groups. However, patients with a short stem, although they required a higher consumption of postoperative analgesics when performing physical activity, returned to sports earlier than those who underwent resurfacing arthroplasty (Figure 6).

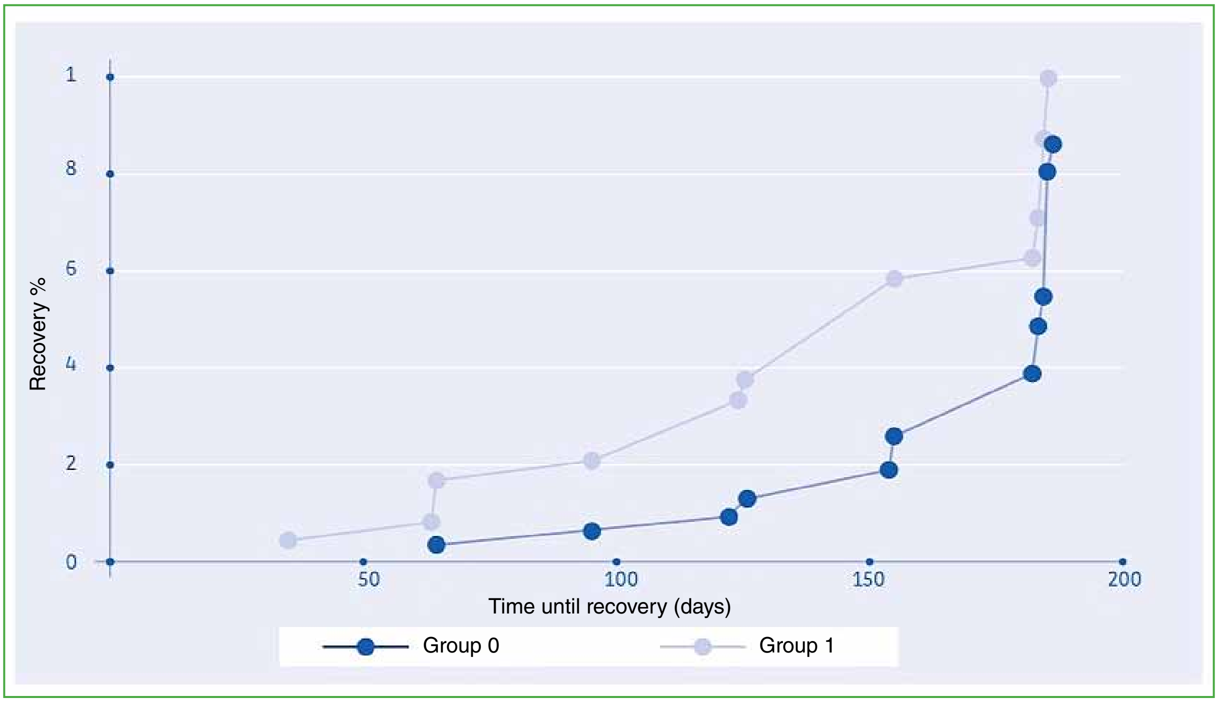

Figure 6. Survival curve of the short stem group (group 1) vs. the resurfacing group (group 0): recovery time in the short-stem prosthesis group was significantly less than that in the resurfacing group ($p = 0.0031$).

5. MEDIUM TERM COMPARISON WITH UNCEMENTED STEMS OF CONVENTIONAL LENGTH

Material and methods

A total of 1100 consecutive primary THAs were studied prospectively, with 20 cemented, 247 hybrid, and 833 uncemented. The latter group received 506 fully hydroxyapatite-coated Corail® tapered stems and 117 MiniHip™ short cervicometaphyseal stems, respectively. The choice of implant was based on patient expectations, proximal femoral morphology, preoperative digital planning, and surgeon choice.

All adult patients <55 years of age were consecutively included; therefore, 300 and 14 were excluded in the Corail® and MiniHip™groups, respectively. Sixty cases operated on with the Corail® stem and two cases with the MiniHip™ stem were lost to follow-up and therefore excluded, leaving 247 uncemented THAs in 220 patients for analysis. In the conventional and short stem groups, 11 and 16 patients underwent bilateral THA in the same procedure, respectively. The mean age of the series was 46 years (range 17-55) ($p = 0.16$). There were 87 and 62 men in the Corail® and MiniHip™ group, respectively ($p = 0.11$). Median follow-up was 7.7 years (range 5-10) for the conventional stem group and 7.3 years (range 5-9) for the short stem cohort ($p = 0.07$).

Results

There was no difference in mean surgical time and mean hospitalization time between the two groups. None of the patients required a blood transfusion. There was a significant improvement in the HHS when comparing the preoperative and postoperative values in both groups ($p < 0.001$).

Mean femoral neck length preservation was double in patients treated with a short stem [13.6 mm for the conventional stem vs. 25.9 mm in the short stem ($p = 0.001$)] (Figure 7), while the mean diaphyseal invasion was three times less in the short stem group [114.5 mm vs. 39.7 ($p = 0.001$)].

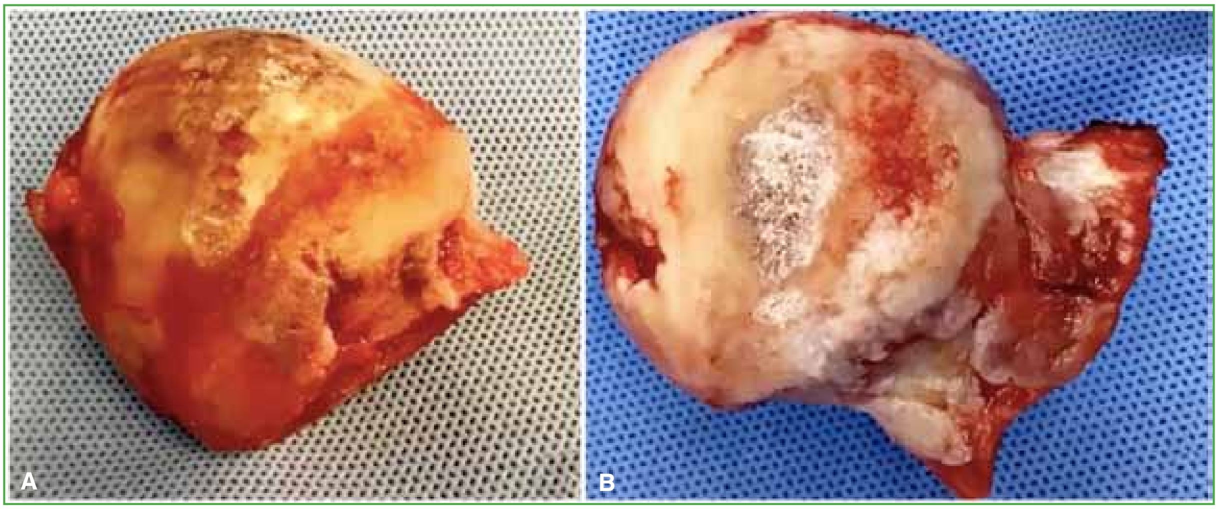

Figure 7. A. Anatomical specimen of the femoral head with the subcapital osteotomy of the neck in a short-stem arthroplasty. **B.** Anatomical piece with a basicervical osteotomy, in an arthroplasty with a conventional femoral stem.

Twenty (8.1%) THAs presented symptomatic metaphyseal radiolucencies around the stem in the Corail® group (p = 0.001), all in Gruen's zones[31] 1, 7, 8 and 14 and were detected after the first postoperative year, with radiographic progression and clinical relevance during follow-up. There was no evidence of osteolysis of the prosthesis around the femoral component. Six (4%) and five (5%) patients in the Corail® and MiniHip™ groups respectively presented initial femoral subsidence <3 mm, with no further progression, and no symptoms until the last follow-up (p = 0.75).

In the conventional stem group, five cases had aseptic loosening of the femoral component due to metaphyseal debonding,[39] treated with a single-stage revision (p = 0.06), and one case had septic failure that was treated surgically with a two-stage revision (p = 0.41).

Five hips (3.4%) in the Corail® group and three (3%) in the MiniHip™ group suffered an intraoperative periprosthetic femoral fracture (p = 0.84). All but one were undisplaced calcar fractures without involvement beyond the lesser trochanter (Vancouver A2) and therefore treated with wire cerclage and partial load without sequelae. The remaining patient in the MiniHip™ group was revised to a conventional hydroxyapatite-coated stem (MetaFix™) due to intraoperative perforation of the lateral cortex (Vancouver A1).

Symptomatic metaphyseal femoral radiolucency[39] was evidenced in 13.7% of the patients in the Corail® group (20 vs. 0, p = 0.001). This phenomenon was related to increased BMI, Dorr B morphology, and a hard-hard friction surface (metal-metal or ceramic-ceramic). All patients reported tolerable thigh pain during impact sports activities and 10 of them during activities of daily living. Five were lost to follow up. Six refused revision surgery because they found their symptoms tolerable. The remaining nine cases are under follow-up, either awaiting surgery or uncertain whether to undergo the procedure.

Aseptic stem loosening was more frequent in the Corail® group than in the MiniHip™ group [5 (3.4%) vs. 0, p = 0.06)]: Four patients were revised to a modular uncemented fluted stem (ZMR®, Zimmer, Warsaw, IN, USA), and one to a long cemented stem (VerSys®, Zimmer Biomet, Warsaw, IN, USA).

At a mean follow-up of 7.6 years, taking stem revision for any reason as the end point, survival was 95.9% and 99% for the Corail® and MiniHip™ groups, respectively (p = 0.15).

6. COMPARISON OF THE INTRA-OPERATIVE COMPLICATION RATE BETWEEN TWO DESIGNS THAT PARTIALLY PRESERVE THE FEMORAL NECK

Material and methods

A prospective analysis of a consecutive series of 190 cases who underwent primary THA was performed, 89 of whom were treated with a collum femoris preserving short stem (CFP™, LINK, Germany) and 101 with a MiniHip TM short stem.[40] Both were classified as "partial column" designs with neck-preserving osteotomy, as described by Falez et al.[41] The main objective of this study was to compare the clinical and radiological outcomes of both stems, with special interest in intraoperative periprosthetic fracture (IPPF).

The series consisted of 151 men and 39 women, the distribution was similar between the two groups (p = 0.12). The mean age was 47 years (SD ± 8.92), with no statistical difference between the two groups (p = 0.93). The mean BMI was 28 kg/m^2 (SD ± 4.06). The diagnoses that led to surgery were as follows: primary osteoarthritis in 151 cases, avascular necrosis in 18 cases, dysplasia in 16 cases, post-traumatic degenerative changes after acetabular fracture in four cases, and idiopathic chondrolysis in one case. There were no statistical differences regarding the distribution of diagnoses between both groups (p = 0.816). The median follow-up was 72 months (interquartile range [IQR]: 66-81), with no differences between both groups (p = 0.43).

Radiological evaluation was performed using an anteroposterior radiograph of the pelvis, a modified Dunn's lateral axial view, and a false profile view. Postoperative radiographs were analyzed to detect osteolysis and eventual progressive radiolucency and subsidence. All intraoperative and postoperative complications, whether related or unrelated to the surgical procedure, were documented.

Patients were prospectively followed up at 2 weeks, 6 weeks, and 3 and 6 months after surgery, and annually thereafter. The patients were evaluated before and after the operation with the modified HHS (mHHS).

Results

Mean mHHS improved from 54.39 (SD ± 10.53) to 95.93 (SD ± 2.73) in the MiniHip™ group (p <0.001) and from 64.07 (SD ± 10.39) to 98 .21 (SD ± 2.86) in the CFP™ group (p <0.001). Four patients showed initial subsidence (<2mm) in the MiniHip™ group, all of them asymptomatic. There were no cases of subsidence in the CFP™ cohort and there were no differences between the two groups (p = 0.643). There were 0 and 2 (2.25%) cases of proximal femoral osteolysis around the MiniHip™ and CFP™ stems, respectively (p = 0.834). Femoral radiolucencies <2 mm wide were observed around two MiniHip™ stems (1.98%) and six CFP™ stems (6.74%) (p = 0.15), without clinical relevance. The median resorption of the femoral neck was 1 mm in the MiniHip™ group (IQR 1-2) and 0 mm in the CFP™ group (IQR 0-1) (p = 0.06). The median hypertrophy of the lateral cortex was 0 mm for both groups (p = 0.306), while cervical hypertrophy was observed in three cases of the MiniHip™ stem and four of the CFP™ group (p = 0.708).

No significant differences were observed in terms of loosening, infection and instability. In total, there were five postoperative complications (2.63%), four in the MiniHip™ group and one in the CFP™ group. There were two aseptic loosening of the acetabular component (treated with revision single-stage THA) and one acute surgical site infection in the MiniHip™ group, which was successfully treated with implant-preserving irrigation and debridement. In addition, there was one case of Vancouver B2 postoperative periprosthetic fracture after an accidental fall 45 days after surgery. The patient underwent revision surgery with an uncemented modular ZMR® stem. In the CFP™ group, only one septic loosening was evidenced which was treated with a revision single-stage THA with an uncemented primary porous cover cup and a distally fixed uncemented modular ZMR® stem. There were no cases of instability or residual pain in the thigh in any of the cohorts.

Regarding intraoperative complications, in total, six IPPF were observed.

(7/190 = 3.68%), three in the MiniHip™ group (1 Vancouver type A1 and 2 type A2) and three in the CFP™ group (3 Vancouver type B2 and 1 type C3). In the MiniHip™ group, there was one lateral cortical perforation categorized as Vancouver A1, which was immediately revised to a conventional hydroxyapatite-coated uncemented stem (MetaFix™) on the same day of surgery. In addition, there were two (2%) intraoperative incomplete calcar fractures (Vancouver A2) of which only one required wire cerclage and partial offloading for 30 days. These two cases occurred at the time of stem insertion and neither of them required a subsequent surgical procedure.

In the CFP™ group, three cases of IPPF occurred. One case with incomplete calcar fracture occurred during definitive stem insertion, and was treated with multiple cerclage.

The second case was diagnosed on the immediate postoperative radiograph, in which a non-displaced femoral shaft fracture was diagnosed, which did not require surgical treatment other than unloading of body weight. The third case occurred during progressive curettage and was classified as Vancouver C3, thus ultimately the CFP™ stem could not be inserted. Therefore, a fully porous coated uncemented conventional stem (LCU, Waldemar Link GmbH & Co, Hamburg, Germany) associated with a 4.5 mm locked compression plate was revised. None of the cases required a new surgical procedure or revision of the femoral stem.

7. MEDIUM-TERM RESULTS IN PATIENTS WITH DEVELOPMENTAL DYSPLASIA OF THE HIP

Material and methods

A consecutive series of 116 patients diagnosed with hip dysplasia and treated with type 2B cervicometaphyseal preservation stem was prospectively studied to analyze the technical problems encountered when reconstructing the proximal femur of patients with osteoarthritis secondary to congenital hip dysplasia treated with a THA using a short stem.[42]

The patient population consisted of 11 women and 6 men with a mean age of 43 years (SD ± 9.97). In five of the cases, the hip dysplasia was bilateral; in one case, bilateral THA was performed in a single procedure, and in four of these hips, sequential surgical treatment was performed at different stages due to the potential complications of complex single-stage bilateral surgeries that require significant reconstructions. The mean BMI was 27 kg/m^2 (SD ± 4.50). Four cases presented a history of pelvic osteotomy during childhood (2 Salter osteotomies and 2 Chiari osteotomies), while four cases had undergone a derotation osteotomy and a varus osteotomy of the femoral neck. The mean follow-up was 41.22 months (range 24-61).

Imaging evaluation was performed using an anteroposterior radiograph of the pelvis, a modified Dunn's lateral axial view (45° hip flexion, foot in neutral rotation), and a false profile view. The degree of hip dysplasia was classified as described by Hartofilakidis,[43] Wiberg's lateral center-edge angle, and Crowe's classification.[44,45] The degree of preoperative osteoarthritis degeneration was characterized with the Tönnis classification.[30] The average lateral center-edge angle was 5.37° (SD ± 6.97). Eight cases were scored as Crowe 1, four as Crowe 2, and 10 as Crowe 3. Similarly, 10 hips were classified as Hartofilakidis A, 10 as B, and two as C. The preoperative mean lower limb length discrepancy, which was assessed by measuring the distance between the line between the teardrop images and the center of the femoral head, was 17.33 mm

(SD ± 10.87).[20] The overall preoperative anteroposterior cervicodiaphyseal angle was 140.6° (SD ± 6.32), while the mean preoperative offset difference between the contralateral and affected sides was 5.3 mm (SD ± 8.44).[21]

Intraoperative and postoperative complications related to the surgical procedure were recorded. Loosening of the acetabular and femoral components was assessed according to the methods described by De Lee and Charnley,[46] and by Gruen et al.,[47] respectively, comparing the immediate postoperative radiograph with that obtained at the last follow-up. Radiographic assessment of stem fixation was assessed in accordance with Engh et al.[36] Any reoperation performed to correct the undesirable sequelae of the previous surgery, with or without the addition, removal, or replacement of components, was considered therapeutic failure.

Results

All patients showed a statistically significant improvement when comparing the preoperative and postoperative mHHS values (54.19 vs. 94.57; $p = 0.0001$) and visual analogue pain scale (8.71 vs. 0.71; $p = 0.0003$). No cases of thigh pain, instability or infection were found. One case of loosening of the cup and one case of periprosthetic fracture of the femur were diagnosed at 8 months and 45 days, respectively. Overall survival was 84.7% at 5 years (95% CI 64.4-105.3) considering revision for any reason as therapeutic failure. When stem performance was evaluated considering reoperation failure due to loosening of the stem only, the survival rate was 100% at 5 years (Figure 8).

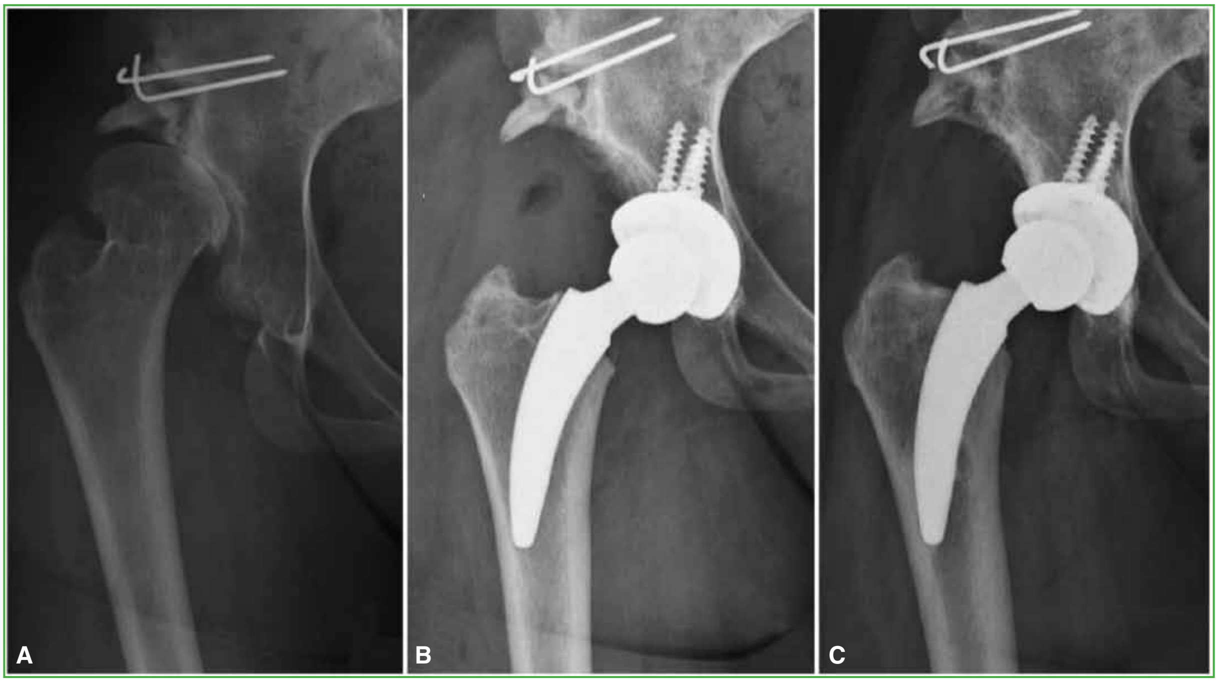

Figure 8. A. Anteroposterior radiograph of the right hip. A 25-year-old woman with dysplastic coxarthrosis Hartofilakidis grade B and coxa valga, and a history of pelvic osteotomy during childhood. **B.** Immediate postoperative anteroposterior radiograph of the patient's hip after femoral reconstruction with a partially neck-preserving MiniHip^{TM} uncemented short stem. **C.** Anteroposterior radiograph of the patient's hip at 5-year follow-up showing stable stem fixation with no signs of implant loosening or subsidence.

8. COMPLEX SITUATIONS

MEDIUM TERM RESULTS IN PROXIMAL DEFORMITIES OF THE FEMUR

Proximal femoral deformities are generally a consequence of developmental diseases of the hip during childhood, previous osteotomy failures, or fracture sequelae (Figure 9).

Anatomic abnormalities of the proximal femur can make biomechanical reconstruction challenging. This surgical procedure has been associated with technical difficulties, prolonged surgical time and approach, high complication rates, the need for more than one surgery, and poor functional outcomes.

Material and methods

Thirty-one patients (35 hips) with proximal femoral deformities treated with uncemented primary THA using a short stem with cervicometaphyseal fixation (MiniHip^{TM}) were prospectively analyzed. There were 19 male (23 hips) and 12 female (12 hips) patients, with a mean BMI of 26.7 ± 4.1 kg/m^2. Twelve cases (38.7%) had a history of surgical procedure, and six of them were failed childhood osteotomies. The mean age of the series was 44 ± 12 years, the mean follow-up was 81 ± 27 months, and there were no patients lost to follow-up. Proximal femoral deformities were categorized according to a modified Berry classification.[48] The preoperative femoral cervicodiaphyseal angle varied between 90° and 157°. The average preoperative discrepancy in lower limb length was -16.3 mm (range -50 to 2). Compared with the contralateral hip, preoperative femoral lateralization averaged -7.6 mm (range -28 to 8).

Clinical outcomes and pain were assessed using the mHHS[49,50] and the visual analog scale, respectively. Postoperative radiographs were analyzed to determine the presence of osteolysis, radiolucencies, subsidence and loosening of the stems according to the Engh method.[36] Postoperative complications and survival rate were also recorded.

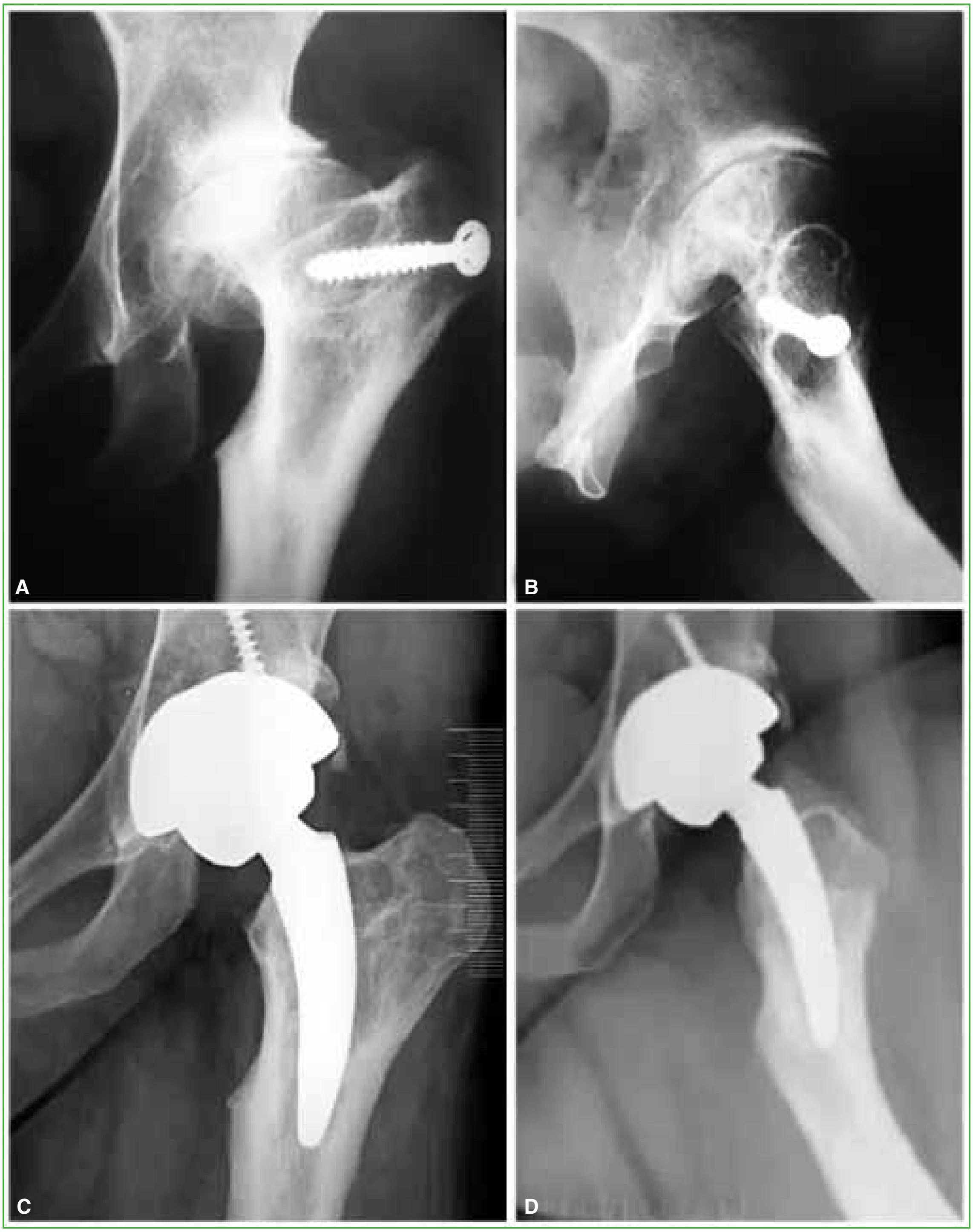

Figure 9. Preoperative anteroposterior (**A**) and lateral (**B**) radiographs of the left hip, showing the proximal deformity of the femur and the osteosynthesis material. Anteroposterior (**C**) and lateral (**D**) radiographs in the immediate postoperative period. The total hip replacement is shown with a short stem and proper alignment in the femoral canal.

Results

At a mean follow-up of 81 months, the survival rate was 97.1% taking revision of the stem for any reason as therapeutic failure and 100% taking aseptic loosening of the femoral component exclusively. An additional femoral osteotomy was not required in any case. The average surgical time was 66 minutes (range 45-100). There was a significant improvement in mHHS when comparing preoperative and postoperative values (47.3 ± 10.6 vs. 92.3 ± 3.7, $p = 0.0001$).

Regarding pain assessment, the mean preoperative value was 8.6 ± 1 and the mean postoperative value was 1.1 ± 1.1 ($p = 0.0001$). The postoperative length discrepancy was, on average, 1 mm (range -9 to 18) ($p = 0.0001$). Postoperative femoral lateralization differed, on average, 29 mm (range -16 to 20) compared to the contralateral side ($p = 0.0001$). No cases of IPPF were registered. There was no evidence of periprosthetic osteolysis around the femoral stems. A uniform, <2 mm wide, radiolucency of the femoral stem was observed in Gruen's area 1, without clinical relevance.

Four patients presented initial femoral collapse (<3 mm), without further progression and without symptoms until the last control. According to Engh's criteria,[36] all stems were classified as stable with no signs of loosening at the end of follow-up. Postoperative complications included one pulmonary thromboembolism, one neurogenic sciatic pain without paresis (complex regional pain syndrome), one transient sciatic nerve palsy that fully recovered after six months, and two acute periprosthetic joint infections that were successfully treated with debridement, antibiotics and retention of the implant. One patient sustained a postoperative Vancouver B2 periprosthetic femoral fracture 45 days after surgery and was revised with a distal fixation modular uncemented fluted stem.

DISCUSSION

In this multi-objective study, we found that short cervicometaphyseal fixation stems can radiographically preserve up to 42% of the femoral bone stock, adequately reconstruct the biomechanics of the hip in relation to the contralateral hip, allow a return to sport in the same way as a surface replacement (and often earlier), have a 97% medium-term survival rate, and have a failure rate no less than that of a partial neck-preserving stem and even no less than that of a conventional one established with 25 years on the market, making them very useful in cases of hip dysplasia and proximal femur deformity.

Despite advances in prosthesis design and surgical technique, anatomical reconstruction of the hip remains a considerable challenge. When an anatomic reconstruction of the hip is not achieved, the results are often unsatisfactory.[50] Discrepancies in femoral length and lateralization are responsible for generating alterations in contiguous joints, such as the knee or the lumbosacral spine, and represent one of the greatest causes of medical litigation in the United States.[34,50-52] Regardless of the prosthetic system used, all stems have the ability to radiographically restore the biomechanics of the hip.[29] However, the short stem appears to be superior to other systems in restoring length to the lower limbs.

It has been shown[29] that the average limb discrepancy is only 1.76 mm (range -4.7 to +7 mm), while the average femoral lateralization difference is 4.56 mm (range -4 to +7) with short stems, which is acceptable if compared with those of other series in which the control of these parameters has been less predictable.[53] Unlike surface arthroplasty, we believe that the learning curve for the short stem can be quickly overcome, allowing the patient to preserve femoral bone stock, especially in young and active people, with less risk of intraoperative complications, as described for surface replacement.

Today's hip surgeon is increasingly confronted with an active patient with high functional demands that must be met through implant selection and periodic follow-up, warning about potential risks directly related to physical activity intensity. Physical activity benefits both operated and non-operated patients, according to the literature. According to current recommendations, patients who participate in sports with high demand for the joint such as individual tennis, soccer, squash, basketball, running, karate, or volleyball after surgery have a higher risk of complications.[54] The remarkable long-term results obtained with hydroxyapatite-coated stems, including 95% fixation at a 25-year follow-up and a zero rate of wear with the ceramic-ceramic friction pair, encourage the use of an implant with these coating conditions and a surface that preserves periprosthetic bone tissue.[26] Complications regarding the level of ions in the blood and ALVAL (acute lymphocytic vasculitis and associated lesions) have currently limited the use of metal-on-metal prostheses (that is, surface prostheses) to selected male patients.

There is strong evidence that conventional femoral stems provide excellent short, medium, and long-term outcomes.[1,55,56] With the growing interest in cementless short femoral stems, a comparative analysis was performed between a time-honored conventional stem and a type 2B short stem that partially preserves the femoral neck.[38] In this study, although the latter showed excellent survival and similar functional results, it preserved twice the femoral neck length and had three times less diaphyseal invasion than the conventional length stem. Symptomatic metaphyseal femoral radiolucency was evidenced in 13.7% of the patients in the conventional stem group (20 vs. 0, p = 0.001); however, no significant differences were found in terms of the overall rate of IPPF, infection, or instability. On the other hand, the rate of aseptic loosening was greater in the conventional stem group than in the short stem group [5 (3.4%) vs. 0, p = 0.06)]. Steinbrück et al.[57] used propensity score matching to harmonize confounding factors related to patient demographics (such as age and sex), volume of surgeries, and joint friction surface in order to examine the potential patient selection bias between short-stem and conventional THA. Using the Kaplan-Meier survival method to estimate the cumulative probability of revision, the authors showed that, when using raw data, the short stem group had a lower cumulative probability of revision than the conventional stem group by up to four years after surgery (p = 0.0001). The authors concluded that the short-stem THA did not present any discernible disadvantages compared with the conventional stem in terms of surgical revision in the short and medium term.

The association between a THA with a short stem and a higher incidence of periprosthetic fracture is dissimilar in the literature. Li et al.[58] reported an IPPF rate of 7% using the CFP™ prosthesis, which were treated conservatively, in all cases, without the need for revision at a mean follow-up of 4.7 years. We believe that technical errors, such as an incorrect cervical osteotomy level (too close to the lesser trochanter) and an inappropriate entry point during femoral canal preparation, are crucial in short, curved stems to avoid calcar cracking or a fracture with diaphyseal extension. Likewise, stems with great curvature ("banana" type), such as the CFP™ design, can increase the risk of intraoperative fracture. A very low neck osteotomy may result in the stem being placed in extreme valgus alignment, which could fracture the femur at the diaphyseal level upon contact with the lateral cortex.[40] However, this finding requires further investigation because the available literature fails to determine whether optimal alignment of short stems should account for various femoral morphologies to prevent IPPF.[59] However, any short varus stem should be inserted lightly to bring the tip of the implant into contact with the lateral cortex for a third fulcrum.[60]

THA with a short-stem prosthesis has already shown excellent clinical

and radiological outcomes in the medium and long term,[61,62] with a variable survival between 92.2% and 100%.[63-66] However, not all designs are similar in size and shape;[13] therefore, different load distributions towards the proximal femur can trigger different patterns of bone remodeling, generating different clinical and radiological outcomes.[13,33] When postoperative thigh pain is diagnosed, understanding its potential etiologies is critical to selecting the appropriate treatment modality. Initially, attempts were made to reduce structural stiffness with modern uncemented stem designs;[67] however, excessive stress transfer from a flexion stiffness mismatch has been a concern in terms of mechanical alterations in the proximal femur's modulus of elasticity, and pain production is a potential consequence.[67,68] With the advent of short stems, much research has focused on thigh pain, and many more recent theories have emerged to explain its genesis.[13,33] In some situations, postoperative radiographs may show cortical hypertrophy as a consequence of bone remodeling that is almost always an asymptomatic event. Maier et al. have analyzed the clinical and radiological outcomes of their first 100 consecutive THAs with the Fitmore® stem (Zimmer, Warsaw, IN, USA).[69] After a mean follow-up of 3.3 years (range 2-4.4), survival was 100% considering revision for any reason as failure, without reporting loosening of the femoral component. However, cortical hypertrophy was observed in 50 hips, predominantly in Gruen's zones 3 and 5.[47,69] Of these, two patients reported moderate pain in the thigh that worsened during physical exercise.

That said, in Argentina, a case of unusual stress fracture has been reported in a 43-year-old man, a professional golfer, at the lateral distal tip of a short uncemented stem with metaphyseal fixation[70] (Figure 10).

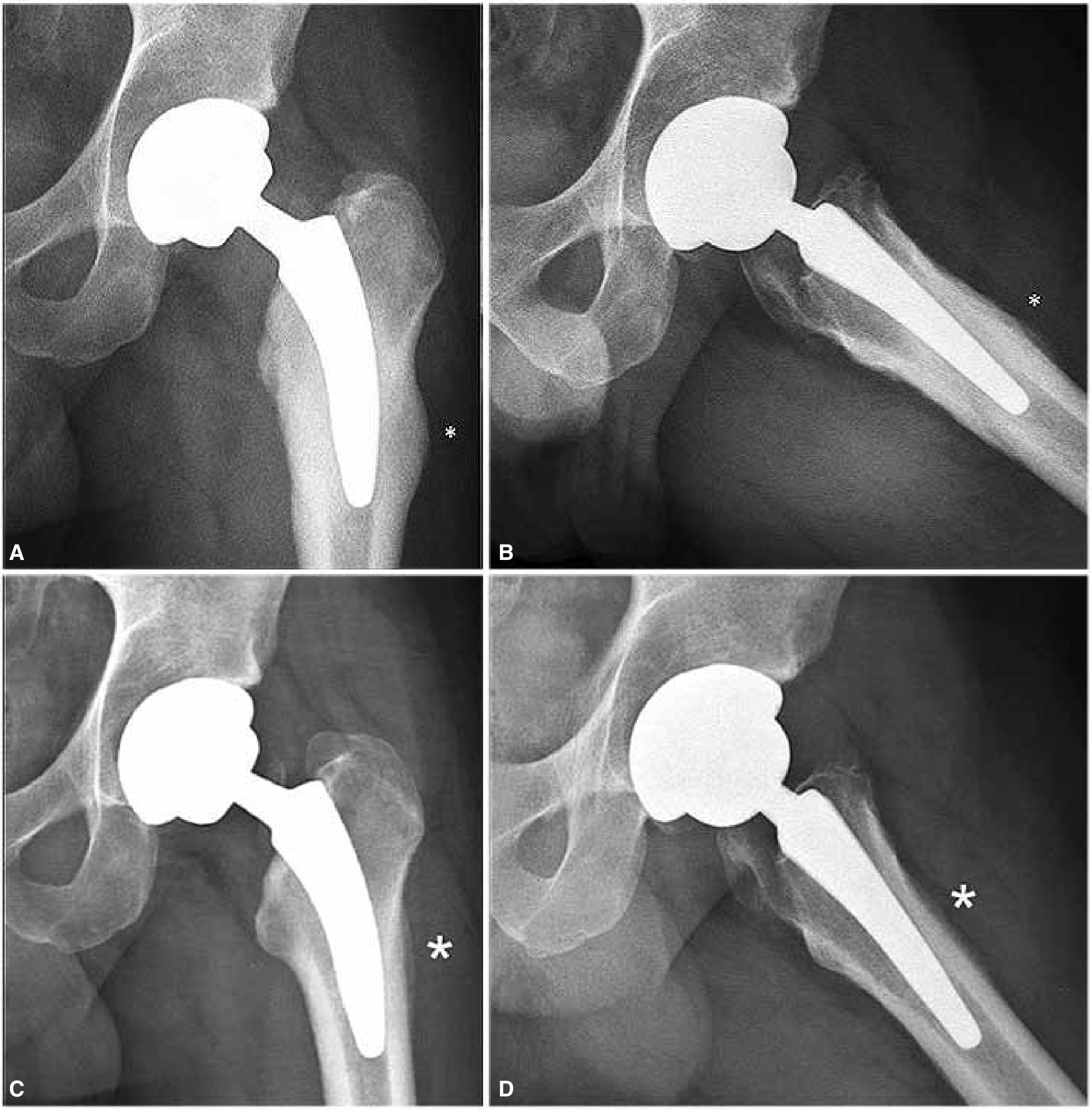

Figure 10. Anteroposterior (**A**) and lateral (**B**) radiographs of the hip of the same patient at the 8-month follow-up. Bone remodeling and periosteal reaction located in the lateral and anterior femoral cortex (*), which correlated with incessant pain exacerbated with axial load. There are no signs of sinking or loosening of the prosthesis. Anteroposterior (**C**) and lateral (**D**) radiographs of the left hip at 2.5 years of follow-up. The hypertrophic callus (*) is visualized, without signs of loosening of the stem. Completely asymptomatic patient.

After ruling out infection and loosening, the authors recommend that reconstructive surgeons be aware of periprosthetic stress fractures as a source of (sometimes overlooked) thigh pain, and that, while rare, these cases should always be considered, given that these cases can be managed conservatively with rest and partial offloading. As previously stated, the stem should be slightly in varus to distribute loads evenly in the medial calcar and lateral femoral cortex.[42,71]

Historically, many prosthetic systems have been used for the treatment of dysplastic coxarthrosis. However, the reference pattern for its treatment is still a matter of debate, since anatomical alterations of the proximal femur (coxa valga extrema, coxa vara due to previous osteotomy, previous osteosynthesis, increased femoral anteversion, marked lower limb length discrepancy, etc.) make implant selection complex.[72] The proximal-distal femoral anatomic mismatch found in dysplastic hips often poses a challenge when deciding on the stem to reconstruct the femur (Figure 11).

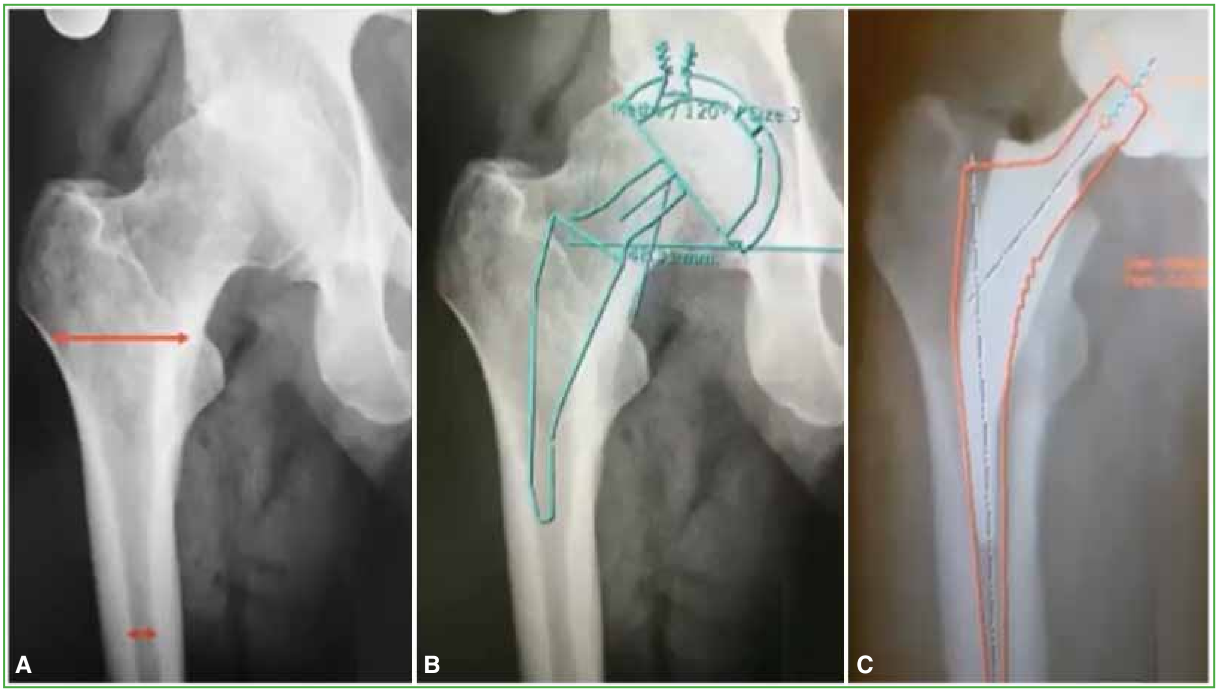

Figure 11. Anteroposterior radiograph of the right hip. The discrepancy between the proximal metaphysis and the diaphysis is observed, in a Dorr A femur (**A**). **B.** Preoperative digital planning with a short stem. The correct filling of the proximal metaphysis is visualized. **C.** Digital preoperative planning with a conventional uncemented stem. Engagement of the distal segment of the stem in the femoral diaphysis is observed.

Conventional length uncemented femoral components rely on proper proximal bone-host contact, which requires excellent fit and filling with resistance to rotational torque to restore hip biomechanics. However, the potential stress shielding remains latent and could cause a massive deficiency of femoral bone stock, making revision surgery a new challenge in the future.[73,74] In this regard, alternative modular femoral components with proximal coating and metaphyseal fixation have been designed, such as the S-ROM (DePuy). Although this implant allows an adequate reconstruction by combining the distal proximal anatomy, it has the problem of modularity. Since most patients with dysplastic osteoarthritis are very young, long-term revision surgery is likely to be necessary, and ideally there are no metallic interfaces that can generate extra debris and wear to the polyethylene wear. In this scenario, preserving bone by using short stems that preserve the femoral neck would allow for an easier final reconstruction.[75] Short stems have shown their usefulness to reconstruct the biomechanics of the hip in cases of dysplasia with a low prevalence of bone alterations and a low rate of revision surgery.[76]

Deformities of the proximal femur can occur at any level. Likewise, they increase the technical difficulty and present a high risk of intraoperative complications, such as fractures or cortical perforation, especially when there are long-standing previous osteosynthesis elements (Figure 12).

Figure 12. A. Preoperative anteroposterior radiograph. Post-traumatic osteoarthritis in a hip treated with plate and screw osteosynthesis. **B.** Immediate postoperative lateral radiograph and immediate postoperative anteroposterior radiographic image (**C**). The joint replacement with a short stem is shown, with removal of the cervical screw and retention of the internal fixation plate.

Treatment of a proximal femoral deformity requires clinical judgment. Anatomy restoration efforts are critical because residual uncorrected deformities can have negative biomechanical consequences. Throughout our experience with short stem implants, we have found that they are advantageous in cases of proximal femoral deformities, because they can avoid concomitant femoral osteotomies, and because they can be inserted while avoiding the total or partial removal of previous implants.[45,77,78] Additionally, they can compensate for extra-articular deformities at the diaphyseal level (more distal).

CONCLUSIONS

1. Bone preservation associated with the use of short stems could bring long-term benefits in young patients with high functional demand.

2. Similar to conventional length stems and resurfacing prostheses, the use of a short stem effectively restores the biomechanics of the hip.

3. A type 2B short stem has achieved excellent survival outcomes at 2-5 years of follow-up, with 1% failure.

4. Like resurfacing prostheses, the short stems allow an early return to the physical activity sought by young patients with advanced hip osteoarthritis.

5. At medium-term follow-up, a short stem with partial femoral neck preservation demonstrated excellent survival rates and functional outcomes comparable to a well-established conventional stem; however, it demonstrated a lower rate of complications.

6. THA with a short type 2B stem for the treatment of dysplastic osteoarthritis would pose very few intraoperative technical problems, it is a useful alternative for femoral reconstruction.

7. In complex scenarios with deformities of the proximal femur, the use of short stems shows advantages, avoiding the need for preoperative and intraoperative corrective osteotomies.

After analyzing the institutional experience with short stems over a 10-year period, the authors of this study believe that the indication of this type of femoral implant is justified in young and active patients, not to outperform the proven results with reliable conventional implants, but to reproduce them with less femoral bone stock consumption.

Conflict of interest: The authors declare no conflicts of interest.

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