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ORIGINAL ARTICLE

# The impact of subsidence on straight and curved modular cementless revision stems in hip revision surgery☆

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**KEYWORDS**
Straight modular stems;
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**Abstract** Subsidence is one of the potential complications in femoral stem revision total hip arthroplasty surgery, and can affect stability and osseointegration.

A retrospective study was conducted on the outcomes at one year and 5 years (specifically subsidence and clinical relevance) of 40 consecutive femoral total hip arthroplasty revisions, comparing two modular cementless revision stems, straight vs. curved, with 20 patients in each group. No mechanical failure was observed, and there was an improvement in functional outcomes. Mean radiological subsidence was 9.9 ± 4.9 mm (straight = 10.75 mm vs. curved = 9.03 mm), with no statistically significant difference between groups ($p$ = 0.076). Fourteen patients (35%) had ≥10 mm of subsidence, up to a maximum of 22 mm.

The subsidence found in this study is similar to published series, with no short-term clinical manifestations, or an increased number of complications or stem loosening in either the straight or curved group. No differences in subsidence were observed at one year and 5 years after surgery between the 2 types of stems.


**PALABRAS CLAVE**
Vástagos rectos modulares;
Vástagos curvos modulares;

**Impacto del hundimiento en vástagos de revisión rectos y curvos modulares en cirugía de revisión de cadera**

**Resumen** El hundimiento protésico es una de las potenciales complicaciones de los vástagos femorales de anclaje diafisario no cementado en las cirugías de revisión protésica, lo cual puede afectar a la estabilidad y a la osteointegración del componente.

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Hundimiento protésico

En este estudio retrospectivo evaluamos los resultados al año y a los 5 años (especialmente el hundimiento y la relevancia clínica) de 40 revisiones de vástago femoral consecutivas, comparando 2 vástagos de revisión modulares no cementados rectos vs. curvos, con 20 pacientes en cada grupo. No se observó ningún fracaso mecánico y se obtuvo una mejoría en cuanto a resultados funcionales en la totalidad de los casos. El hundimiento radiológico medio fue de 9,9 ± 4,9 mm (p = 0,076); 14 pacientes (35%) tuvieron ≥10 mm de hundimiento, con un máximo de 22 mm en un caso.

Nuestros resultados son similares a las series publicadas en la literatura, sin manifestaciones clínicas a corto-medio plazo ni incremento del número de complicaciones o aflojamiento del vástago en ninguno de los 2 grupos. No se observaron diferencias en cuanto al hundimiento protésico al año y a los 5 años posteriores a la cirugía entre los 2 tipos de vástagos.


## Introduction

In recent years, a growing number of patients require the implantation of a total hip prosthesis (THP) as a result of the excellent clinical results obtained with implants of this type. In consequence, due to the limited life of these prostheses, prosthetic revision surgery is growing and will continue to grow in orthopaedic surgery departments.[1] The procedure is extremely complex because of peri-prosthetic bone loss and it may pose a major challenge for an orthopaedic surgeon, who must be aware of the different surgical techniques and the design of the new stems.[2]

The primary bone defect will determine the surgical technique: with or without cement, the use of a graft or otherwise, or the prosthetic system to be used to fix the femoral stem. We can find various models of prostheses available on the market for THP revision surgery and none of them is clearly superior to the others. Nonetheless, cementless models seem to adapt better to femoral revision surgery due to the lower degree of interdigitation of cement inside the femoral channel, which is increased in size as a result of prosthetic loosening and osteoporosis, with 79% of cement strength loss compared to primary arthroplasties.[3,4] More specifically, in 1987, Wagner introduced a new cementless technique using long conical stems with diaphyseal anchorage and obtaining excellent results.[5]

Initially, all stems were straight; however, the emergence of fractures and perforations of the anterior femoral cortex in patients with a narrow isthmus, and especially in endofemoral approaches, led to the development of curved modular stems that attempted to reproduce the anterior femoral curvature. These stems also provided greater rotational stability due to the longitudinal slots in the octagonal cross-section of the implant. Many studies have now confirmed the good outcomes obtained with this type of stem,[6–9] suggesting less subsidence with curved stems,[6] but no study to date has compared curved and straight stems.

We designed this study at our centre to evaluate the radiological outcomes of the subsidence of cementless striated conical modular stems, comparing straight and curved models. Secondary goals included the analysis of the functional outcomes, the complications and the impact of the surgical approach used.

## Material and methods

A retrospective review was performed on 40 patients operated on for THP revision surgery using Revitan® modular stems with diaphyseal fixation (Zimmer GmbH, Winterthur, Switzerland). All the procedures were performed by 3 senior surgeons from the hip unit at out centre (M.C., M.F., L.A.) during the period between December 2008, and December, 2010. The follow-up has continued for up to 5 years.

Two different types of stems were used: Revitan® straight modular stems and Revitan® curved modular stems without lock. The Revitan® system is a cementless modular revision implant made of a titanium alloy; it comprises both a proximal and a distal component. There are 2 types of proximal component: augmented or cylindrical; and 6 lengths available (from 55 to 105 mm in 10 mm increments), a 135° cervical-diaphyseal angle and an offset of 44 mm. The distal component can be straight or curved. The straight stems are conical, with longitudinal ribbing that provides rotational stability; available in 3 lengths (140, 200 and 260 mm) and the diameter increases from 14 to 24 mm in 2 mm increments. Curved stems have an octagonal cross-section giving them rotational stability and they present a sagittal curvature along their longitudinal axis, making the morphology more anatomical, in line with the femoral antecurvature. We have curved stems available with the same lengths and diameters as the straight stems, with the advantage that the 200 and 260 mm lengths can be locked distally with blocking screws in calibres starting from 18 mm.

For this study, the first 20 cases receiving a straight stem and the first 20 cases receiving a curved stem were selected (the curved stem was launched onto the market a year later and these were the first ones implanted at the department), and a comparative study was conducted *a posteriori* between the two groups. The type of prosthesis was chosen by the surgeon during the pre-operative planning, bearing in mind: the length of the osteotomy, the distance from the cement and plug, endofemoral fixation and type of defect.

A comparative study was carried out between the two groups of patients depending on the type of stem implanted, giving 2 groups of 20 patients. In addition, a comparative statistical study was performed on the different variables in both groups.

The group of patients with straight stems had a larger number of patients with the indication of a change due to aseptic loosening (12), and in the group of curved stems there were more patients with peri-prosthetic fractures (5). With respect to the femoral defects, a larger number of severe defects (type III) was seen in the straight stem group, whereas there were more mild to moderate defects (types I-II) in the curved stem group.

There were 20 males and 20 females, with a mean age of $71.1 \pm 12.3$ months. The level of comorbidity and associated pathologies was measured using the scale of the American Society of Anaesthetists (ASA),[10] with a mean value of $2.2 \pm 0.3$ points. The mean period between primary THP surgery and the subsequent revision was $70.3 \pm 59$ months.

The indications for revision surgery were as follows: prosthetic loosening in 20 patients (50%), infection in 10 patients (25%), peri-prosthetic fractures in 7 patients (17.5%) and instability in 3 patients (7.5%). These revision rates were similar to those in other series published.[1,2,6]

With respect to the degree of loosening and the loss of bone stock, these were measured in accordance with the Paprosky classification[11]; 10 patients were classified as grade I (25%), 10 patients as grade II (25%) and 20 patients as grade III (50%). This last group was sub-divided into 3 subgroups: 12 type IIIA defects, 6 type IIIB defects and 2 type IIIC defects, plus 6 B2 peri-prosthetic fractures and one B3 peri-prosthetic fracture.

Two different surgical techniques were used depending on the approach chosen during the pre-operative planning stage. The approach most frequently used was the transfemoral approach using a modified Wagner technique,[6,7] employed in 23 patients (57.5%) presenting with one of the following alterations: stem breakage, femoral deformities corrected by means of osteotomy, revision of cemented stems to facilitate the complete extraction of the cement, or peri-prosthetic fractures with stem loosening, where the approach was facilitated by the line of the fracture itself. The other technique used was the endofemoral approach via the anterolateral route, without osteotomy; it was applied to 11 patients (27.5%). Finally, in the group of patients with infection, 6 (6%) required a two-stage replacement. In the initial stage, the prosthesis was extracted using a modified Wagner transfemoral approach using and a pre-assembled spacer inserted. In the second stage, the spacer was removed and the revision prosthesis component subsequently implanted using the endofemoral route.

## Surgical technique

Straight stems: use of hand-adjusted conical burrs in order to prepare the channel to receive the prosthetic cone. Curved stems: milling with Küntscher burrs to 9–10 mm in size and subsequent use of hand conical burrs. In no case was distal locking carried out with curved stems.

The intra-operative complications, especially fractures, were classified according to the Vancouver classification.[12]

During the post-operative period, the patients followed rehabilitation programme based on the hospital protocol, starting partial loading with 10 kg of weight on the limb during 6 weeks and subsequently increasing the load gradually.

The clinical and radiological follow-up was carried out after 1, 3, 6 and 12 months during the first year and every 6 months thereafter. The functional outcomes were assessed using the Merle d'Aubigné scale[13] and the need for walking aids. The stem subsidence scale described by Callaghan et al.[14] was analysed radiologically using the PACS system, with 2 standard X-rays of the hip complete femur in 2 different planes (anteroposterior and lateral projections), comparing the post-operative images with those of the subsequent follow-ups. The analysis was performed independently by a member of the radiology department. Measurements were taken after one year and 5 years following surgery. Heterotopic calcifications were measured following the criteria described by Brooker et al.,[15] and an analysis was performed on the complications emerging during follow-up.

## Statistical analysis

Quantitative variables were described using mean and standard deviation, whereas frequencies and percentages were used in categorical variables. The $\chi^2$ squared test or Fisher's exact test, as appropriate, was used to establish relationships between two categorical variables. Spearman's correlation coefficient was used to quantify the level of association between two quantitative variables. Values of $p$ less than 0.05 were considered statistically significant. For the statistical analysis, version 15.0 of the SPSS system was used (SPSS Inc., Chicago, IL, USA).

## Results

No patient was lost during follow-up. The analysis of the epidemiological data revealed that there were no statistically significant differences between the 2 groups with respect to age, time between primary and revision surgery, and comorbidities.

A comparative study was carried out between the two groups of patients and the results can be seen in Table 1. No significant differences were found between the groups with respect to the reason for indicating the replacement of their prostheses.

With regard to femoral defects, there were also no statistically significant differences in the distribution in both groups.

No differences were observed between the 2 groups when we analysed prosthetic subsidence (n.s.), although there was a linear trend towards slightly greater subsidence in the straight stems group. No differences were observed between the groups in the rest of the variables studied: degree of loosening prior to the replacement, type of surgical approach, intra- and post-operative complications, patient functionality and the need for walking aids at the end of the follow-up.

The analysis of revision stem subsidence was carried out in accordance with the Callaghan system,[14] obtaining a mean subsidence of $9.9 \pm 4.9$ mm, with 14 patients (35%) showing $\geq$10 mm of subsidence, up to a maximum of 22 mm in one case. Measurements were taken after 1 and 5 years, without any statistically significant differences being obtained, indicating that prosthetic subsidence occurs

**Table 1** Comparison between the 2 groups based on the type of stem implanted and comparative study with different variables.

| Parameter | Total ($n = 40$) | Straight stem ($n = 20$) | Curved stem ($n = 20$) | Value of $p$ |
|---|---|---|---|---|
| *Years* | 71.15 | 72.5 | 69.8 | |
| *Gender (M/F)* | 20/20 | | | |
| *Time between surgical procedures (months)* | 70 | 64 | 76 | |
| *Follow-up (months)* | 11.3 | 12.7 | 9.9 | |
| *ASA* | 2.2 | 2.15 | 2.25 | |
| *Pre-operative diagnosis (N)* | | | | |
| Mechanical loosening | 20 | 12 | 8 | |
| Septic loosening | 10 | 5 | 5 | |
| Peri-prosthetic fracture | 7 | 2 | 5 | |
| Instability of prosthesis | 3 | 1 | 2 | |
| *Femoral defect as per Paprosky (n)* | | | | |
| I | 10 | 2 | 8 | |
| II | 10 | 5 | 5 | |
| IIIA | 12 | 8 | 4 | |
| IIIB | 6 | 4 | 2 | |
| IIIC | 2 | 1 | 1 | |
| *Type of surgical procedure* | | | | 0.337 |
| Wagner's approach | 23 | 13 | 10 | |
| Endofemoral approach | 11 | 5 | 6 | |
| Two-stage replacement | 6 | 2 | 4 | |
| *Intra-operative complications (n)* | | | | 0.695 |
| Femoral fractures | 5 | 3 | 2 | |
| *Post-operative complications (n)* | 13 | 6 | 7 | 0.843 |
| *Subsidence (mm)* | | 10.75 | 9.03 | 0.076 |
| *Subsidence > 10 mm (n)* | 14 | 9 | 5 | |
| *Function* | | | | 0.512 |
| PMA | | 14.5 (±0.8) | 14.1 (±0.6) | |
| *External walking aids (n)* | | | | 0.718 |
| None | 25 | | | |
| 1 walking stick | 12 | 5 | 7 | |
| 2 walking sticks or frame | 3 | 2 | 1 | |

ASA: American Anaesthesiology Scale[10]; PMA: Postel Merle d'Aubigné.[13]

during the first year following surgery. Studying the correlation between prosthetic subsidence and the other variables, we observe a statistically significant correlation between the degree of subsidence and intra-operative fracture of the greater trochanter ($p = 0.048$), and also between the degree of subsidence and the need for walking aids ($p = 0.044$). No correlation was seen with respect to the variables of gender, type of surgical procedure, post-operative complications or patient functionality. Nor were any differences seen after 5 years with respect to subsidence in the 2 types of stem. The correlations are shown in Table 2.

**Table 2** Correlation between subsidence of the prosthesis and different variables.

| Subsidence | Values of $p$ |
|---|---|
| Gender | 0.925 |
| Type of surgical procedure | 0.957 |
| Intra-operative complications | 0.082 |
| Post-operative complications | 0.244 |
| Function | 0.652 |
| Walking aids | 0.044 |

The intra-operative complications observed were 5 fractures of the greater trochanter, all fixed by means of transosseous sutures and with radiographic evidence of subsequent consolidation without further complications. With regard to the post-operative complications, 2 fractures of the greater trochanter were observed in the immediate post-operative period, both treated conservatively; 3 patients presented an isolated episode of dislocation that was reduced under sedation; and one patient came with repeated episodes of dislocation requiring a replacement of the acetabular component due its poor orientation. One patient developed a haematoma under tension at the site of the surgical incision and required surgical evacuation; there were also 3 cases of superficial infection of the wound that were treated successfully with oral antibiotics; and 2 deep infections, one of which was cured following debriding associated with antibiotic treatment, while the other required a two-stage replacement. We had no cases of via falsa position or intra-operative fractures.

Peri-prosthetic calcifications were observed in 31 patients, 20 of which were type I and the other 13 type II. Only 9 patients did not present heterotopic ossifications.

Functional status improved significantly in all patients. The mean score on the Merle d'Aubigné scale improved from 7.9 ($\pm$ 0.7) pre-operatively to 14.2 ($\pm$ 0.8) points at the last follow-up ($p < 0.001$). Twelve patients continued to need a walking stick, while three 3 needed 2 sticks or a walking frame.

## Discussion

During our revision, we found that patients with a Revitan® curved stem showed less subsidence than those fitted with a straight stem. In short, if we choose a subsidence of 10 mm as the cut-off for clinical relevance, less subsidence is observed in curved stems, 5 patients versus 9 patients. As mentioned above, however, we did not find any statistically significant differences between the two groups in terms of complications (whether intra- or post-operatively) or in functionality, with scores of over 14 on the Merle d'Aubigné scale in both groups. These results are similar to those found in the series by Mertl et al.[16] In addition, apart from subsidence, no replacement of prostheses was required in any case for this reason.

Several studies have shown that modular revision stems (also known as ''fit and fill stems'') provide better outcomes than mono-block stems as they allow the more accurate adjustment of the prosthetic component to the cortical bone, both distally and proximally. Moreover, the proximal module can be adjusted in terms of length, offset and morphology (cylindrical or augmented), which improves the biomechanics of bone and soft tissue in the hip. Clinically, this implies a lower risk of dislocation,[2] making modular implants more and more popular in prosthetic revision surgery. It must be remembered that modular designs also have disadvantages, such as higher cost, risk of intra-operative fractures or a greater risk of wear and tear due to their additional interface.

Only one study[16] mentions the advantage of curved over straight stems in reference to surgical failure and clinical outcomes, but the article merely expresses the author's opinion despite providing the results.

Prosthetic subsidence, the main objective of this article, has been extensively evaluated in many studies but none has provided scientific evidence on its significance with respect to complications, revision rate or quality of life among patients.[17] Apart from that, many authors consider prosthetic subsidence as a negative predictive factor for osteointegration of the stem,[18–21] although none of them reaches a conclusion about how many millimetres of subsidence are necessary to affect the surgical outcomes; authors such as Callaghan et al.[14] place the cut-off at 5 mm, while others, including Wagner, set it at 10 mm. All of them agree that subsidence appears in the first 12 months following revision surgery, with a mean period of 6–8 months.[7,22] The risk factors for the occurrence of subsidence include undersized stems, osteoporosis, insufficient metaphyseal stability and transfemoral approach.[23] In our series, we have found a statistically significant relationship between prosthetic subsidence and a history of fracture of the greater trochanter, which we believe is due to less proximal anchorage of the stem.

The differences between curved and straight modular stems described in the scientific literature reveal that, in the case of straight stems, subsidence ranges between 2 and 20 mm occur in 2.7–26% of patients (>10 mm), and in 48–54% of patients in the case of 5 mm of subsidence, depending on the series published. Most of these patients need additional surgery.[24] In a review of 84 cases, Lakstein et al.[23] found 2 patients with 21 mm of subsidence requiring surgical revision.

In a prospective study of 68 curved stem revisions, Fink et al.[6] found no subsidence in 91.2% of the cases. These outcomes are better than those previously reported in the literature on straight stems in prosthetic revisions.

Table 3 compares the degree of subsidence in different series and their implications.

One way to prevent subsidence in the prosthetic component is to use distally locking stems, particularly in patients with peri-prosthetic fractures[29,30] or with major bone stock defects.[9] These were not used in our series of curved stems so as not to interfere with the results.

Furthermore, in order to reduce the subsidence rate, the distal insertion of curved stems is easier and, although this is not our case, some authors report a lower risk of perforation of the anterior cortex due to the physiological anteversion of curved models.[2,8] Similarly, Fink et al.[6] showed that, in the case of Revitan® curved stems, distal fixation in femoral osteotomy is achieved at a depth of 3 cm, compared to the 4–7 cm needed in the case of straight stems.[21,24] For this reason, these authors recommend the use of short, broad stems instead of long models with a smaller calibre.

With regard to the surgical approach, we used both the endomedullary and the modified transfemoral approaches in both groups without distinction. This is an important point as authors such as Fink et al.[6] have stated that, although there are no differences in the long-term outcomes, the modified transfemoral approach has, at least initially (during the first year after the surgical procedure), a higher incidence of Trendelenburg's sign. Despite this, they recommend this approach because of the shorter surgery time, better access to the distal femoral channel (an advantage when removing cement and preparing the bone before implanting the new prosthetic component), the higher probability of correcting axial deformities and an excellent osteotomy consolidation rate (95–100%) with respect to trochanteric osteotomies. We fully agree with all these points. Furthermore, weakness in the gluteus medius is transitory and is due to the low muscle tension achieved after performing osteotomy, causing a biomechanical alteration on the lever arm of the abductor muscles in the hip.

Our study has certain limitations. It is a retrospective study without prior randomisation of the patients, and with the biases inherent to studies of this type. Although the follow-up was limited to 5 years, no increase in subsidence was observed after the first year following the operation, a finding already described by other authors[4,21,31,32]; this leads us to think that the follow-up time has been sufficient to evaluate prosthetic subsidence.

**Table 3** Results published for modular conical stems with distal fixation.

| Author | *n* | Follow-up (months) | Type of stem | Mean subsidence (mm) | Subsidence >10 mm n (%) | Dislocation *n* (%) | Fracture *n* (%) |
|---|---|---|---|---|---|---|---|
| *Böhm and Bischel*[4] | 129 | 97.2 | Wagner | – | 26 (20) | 7 (5.4) | (4.6) |
| *Boisgard et al.*[20] | 52 | 44.4 | Wagner | – | 2 (3.8) | 4 (7.7) | – |
| *Regis et al.*[25] | 41 | 166.8 | Wagner | – | 8 (19.5) | 4 (9.7) | 7 (17.1) |
| *McInnis et al.*[26] | 70 | 47 | PFM | 9.9 | 25 (35.7) | 7 (10) | 17 (24.2) |
| *Park et al.*[27] | 62 | 50 | Lima | 1.1 | 2 (3.2) | 3 (4.8) | 8 (12.9) |
| *Ovesen et al.*[28] | 125 | 50 | ZMR | 2 | – | 8 (6.4) | 4 (3.2) |
| *Current study* | 40 | 11.3 (±4.9) | | 9.9 (±4.9) | 14 (35) | 3 (7.5) | 5 (12.5) |
| Straight | 20 | 12.7 | Straight | 10.75 | 9 (45) | 2 (10) | 3 (15) |
| Curved | 20 | 9.9 | Curved | 9.03 | 5 (25) | 1 (5) | 2 (10) |

Despite these limitations, we can conclude that, although no statistically significant differences have been found, there is a certain trend towards greater subsidence in straight stems compared to curved stems. For this reason, in the light of our experience, we recommend the use of striated curved stems as the first choice in the case of prosthetic revisions as they also offer the possibility of distal locking to improve the initial fixation, thus limiting migration even more.

## Level of evidence

Level IV evidence.

## Ethical disclosures

**Protection of human and animal subjects.** The authors state that the procedures followed complied with the ethical standards of the responsible human experimentation committee and in accordance with the World Medical Association and the Declaration of Helsinki.

**Confidentiality of data.** The authors state that they have followed the protocols of the work centre regarding the publication of patient data.

**Right to privacy and informed consent.** The authors have obtained the informed consent of all patients and/or subjects referred to in the article. These documents are in the possession of the corresponding author.

## Conflict of interest

Fernando Marqués López and Alfonso León García are consultants at the Zimmer Biomet Education Institute. The rest of the authors have not reported any conflicts of interest in this study.

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