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Evaluation of Total Hip Prosthesis Planning Using a Method with CT Images at 115% in Approximately 52 Cases

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Abstract

Introduction: The planning of a total hip prosthesis (THP) is an important step conditioning the success of the intervention itself. Since Müller's description, every school, every surgeon, or every hospital tries to adapt the basic principles to their own method and work context. This study aims to evaluate a THP planning method using scanning at 115% magnification. **Methodology:** Fifty-two first-line PTHs were planned by CT scan at 115% magnification, in 52 patients admitted consecutively to the hospital center of Carcassonne, and were evaluated in order to measure the reproducibility of the method. The size of the implants, the length inequality of the limbs, and the femoral offset calculated pre- and post-operatively were compared. **Results:** The planning of the femoral stem was consistent with the final implant in 69.2% of cases, while that of the cotyloid cup was consistent in 82.7% of cases. Generally speaking, we had about 70% compliance. 94.4% (49) of our patients had postoperative limb length equalization to within 5 mm. The average improvement in terms of length inequality was 1.4 mm. The postoperative femoral mean offset was compatible with normal life. **Discussion:** This method, which is closer to 3D planning methods, seems reproducible for implant size. It seems more precise for the size of the acetabulum without being less precise than other methods regarding the size of the femoral stem and the correction of inequalities in limb length.

Keywords

THP, Planning, CT-Scan

1. Introduction

The planning of a total hip prosthesis (THP) is recognized by all surgeons as an essential step before performing the surgical procedure itself [1]-[4]. It allows evaluation of the length of the prosthetic neck, the size and type of implant to be used, as well as the level of cervical cutting to be performed [3] [5]. According to Yoder *et al.* (Coll.), it is absolutely necessary to restore the length of the limb, the lateralization of the femur, and the position of the center of rotation of the hip in order to optimize the functioning of the prosthesis [6]. Many factors lead to deviation from reality. These include, among others, the local anatomical conditions, the quality of the bone, the radiographic enlargement defects, and the intraoperative testing [3].

From the basic technique described by Müller [7], and modified over the years until the advent of computerized planning, which remains today the gold standard, each surgeon or each school tried to introduce its own devices according to its place of practice, difficulties encountered, experience, and available resources.

The Carcassonne Hospital Center has been using, for some years, a method undoubtedly based on fundamental principles but employing a particular scannographic protocol. This work therefore aims to evaluate this planning technique and analyze its strengths and weaknesses.

2. Patients and Methods

Study material

The study material consists of patient medical records containing hip CT images and pelvic X-rays, transparent plastic planning templates provided by each laboratory for its type of prosthesis, and operating reports.

Regarding the scannographic images used, it is a 3D reconstruction computed tomography allowing the output of three types of useful images, magnified at 115% for planning.

-An image in a coronal section passing through the femoral neck and the middle of the femoral shaft (**Figure 1**), which accounts for the femur, on one hand, for the true limits of the medullary canal and the existence or absence of diaphysial stenosis that may hinder the descent of the stem intraoperatively, and on the other hand, for the acetabulum, the approximate boundaries of the osteochondral zone and its rearrangements (geodes, osteophytes, etc.);

-An image in sagittal section passing through the middle of the femoral shaft (**Figure 2**) allows one to have an idea, also from another angle, of the width of the medullary canal and to anticipate the type of prosthesis to be fitted on one hand and, on the other hand, to suspect a possible torsion of the metaphyso-diaphysis.

-An image in 3D reconstruction in transparency (**Figure 3**) that confirms the information provided by the first two images and synthesizes it.

Protocol for creating scannographic images

This is a scan enlarged to 115% and obtained according to the following technical parameters and procedures:

✓ Position of the patient:

After replacing the table mattress with a hard bed, the patient is positioned supine, with feet slightly rotated internally, hands placed on the abdomen, and the hip scan centered on the table.

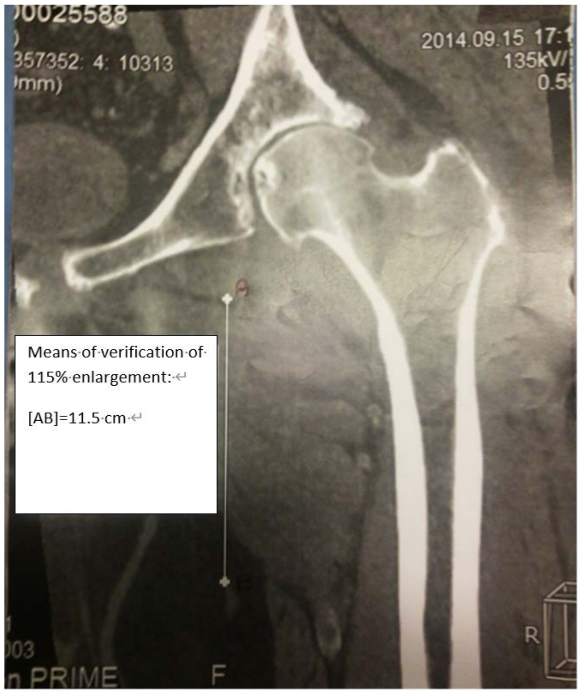

Figure 1. Coronal section scan image.

Figure 2. Sagittal section scan image.

Figure 3. Scannographic image in 3D reconstruction.

✓ Description of the procedure

-Dual scanno: from the half of the femur to the hip-femoral joint.

-Helix: comprising the coxo-femoral joint and the upper half of the femoral shaft.

It is imperative for this acquisition not to change any acquisition parameters at the risk of distorting the magnification of the final image (fov, fields, mag ratio).

✓ Technical parameters

KV	MA	Vit rot	Pitch	Acquired	CTDI	Filters	Recont	Boost	Img filter
120	SD10	0.75	0.844	1X 32		FC02	1X0.8	ON	QDS+

✓ Reconstruction

-By the MPR in the coronal and sagittal plane, we use a reconstruction in MIP of thickness 2. At the same time, we trace a vertical line on each image (sagittal and coronal) with a length of 10 cm. We end with the annotation of each shot (115%).

-By 3D: memorize the front image without touching it by annotating it (hip 115%).

✓ Filming (The 3 types of images in photos)

We release a total of three images:

-An image in the coronal plane passing through the femoral neck and the middle of the femoral shaft (**Figure 1**);

-An image in the sagittal plane passing through the middle of the diaphysis (**Figure 2**);

-A 3D image in transparency (**Figure 3**).

✓ Verification

We check that the vertical line of 10 cm on each image measures 11.5 cm on the final shot.

Methodology

The Antoine GAYRAUD Hospital Center in Carcassonne was our study setting. This is a prospective study conducted over a period of 16 months from November 2013 to March 2015 and involved patients successively admitted to surgery for first-line PTH.

The inclusion criteria were as follows:

-Having been hospitalized at the CH of Carcassonne during the study period.

-Having benefited from first-line unilateral PTH in the hospital.

-Having benefited from the realization of the scanner according to the protocol in force in the department for pre-operative planning.

-Having had simple, immediate operating consequences.

The exclusion criteria were:

-Patients whose planning was not done according to the 3D protocol;

-Patients whose immediate post-operative outcomes were hemodynamically and/or generally complicated.

Fifty-three patients were initially included in the study. We excluded one patient who died immediately after surgery from a massive pulmonary embolism, reducing the sample to 52 patients.

Thus, 52 PTH were performed in 52 patients, including 49 for primary osteoarthritis and 3 for osteonecrosis of the femoral head. The left side represented 30 cases and the right side 32 cases. There were 33 men and 19 women aged 60 to 86, with a mean age of 74. Les marques de prothèses mises dans notre centre sont SEM®, ATF® (Silène et Liberty), ECOFIT® pour les tiges et RM-Mathys®, SEM (EVORA®, GALILEA®), MEDICOSCOP (ACTIV®, CAPTIV®) pour les cupules.

- **Preoperative planning**

✓ Choice of the size of the femoral implant

The size of the femoral stem is determined on the 3D scan image in transparency and on the coronal section image. Depending on the brand of the prosthesis, we use the corresponding abacuses or templates provided by the laboratories concerned and enlarged to 115%, like the CT images used. All the sizes of the different rods were represented on these charts. The ideal stem size was obtained by superimposing the medial edge of the abacus on the medial edge of the medullary canal of the femur so that the T-line (trochanteric line) is well placed at the top of the greater trochanter. The line R, corresponding to the resection line, is located, allowing an approximate measurement of the femoral neck cut level.

The approximate cut level of the cervix corresponds to the intersection between the medial collar edge and line R. The distance from this point to the most prominent point of the lesser trochanter is measured and expressed in millimeters (**Figure 4**).

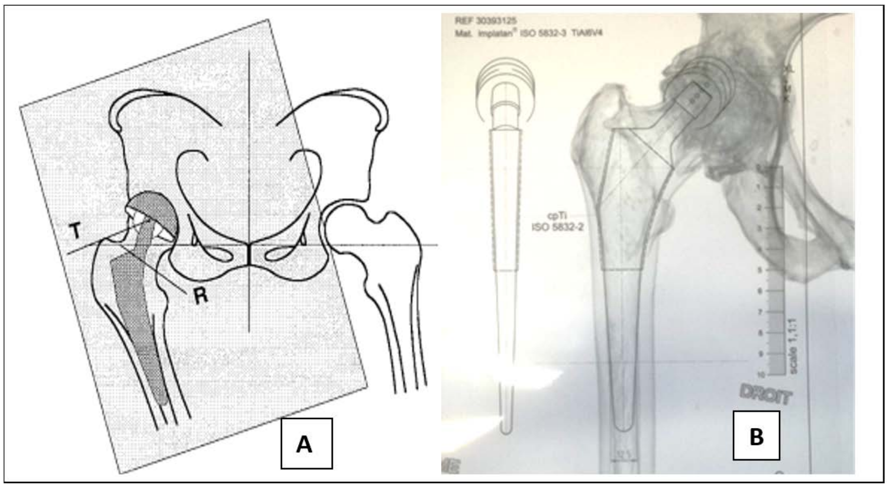

Figure 4. In A, point T and line R allow the placement of femoral abacuses to determine the size of the stem and the approximate level of cut [1]. In B, determination of the size of the rod using the 3D reconstruction scanner by transparency.

✓ Choice of the acetabulum

With the CT image in a coronal section through the neck of the femur and the middle of the diaphysis, the most suitable size for the acetabulum is determined using the abacus, taking into account the particular characteristics of the prosthetic cup and the method of fixation [8]-[11].

The inclination of the abacus of the cotyle relative to the horizontal of 40˚ was respected. Taking into account the morphological particularities (protrusion, osteophyte of the bottom, subluxation), position the layer of the acetabulum in the desired place and note the most suitable size [9] [10]. The center of rotation imposed by the laboratory was thus identified and taken as the approximate center of rotation of the hip (Figure 5).

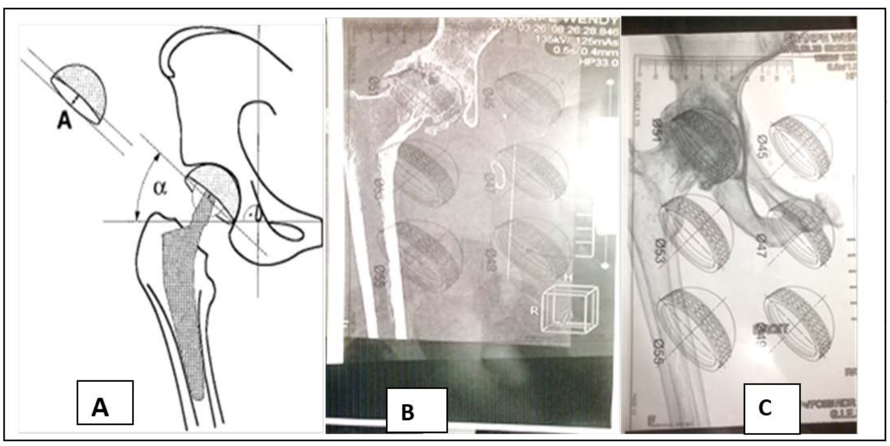

Figure 5. In A, positioning of the cup: about 40° with the horizontal. In B, determination of the cup size on a coronal section passing through the middle of the femur, and in C, verification on a 3D reconstruction image in transparency.

✓ length inequality

The inequalities in limb length that existed in 8 of our patients (15.4%) prior to surgery were clinically measured and ranged from −35 mm to 50 mm, with a mean value of 11 mm (Standard Deviation SD = 25 mm).

✓ Operator

The patients included in the study are those of the three different orthopedic and traumatological surgeons available at the hospital. Preoperative planning was done by an independent surgeon and then by the operating surgeon himself. For each size selected, whether for the stem or the cup, we frame it with a size below and a size above.

- **Operating protocol**

All PTH in our study were placed posteroexternally by experienced surgeons. These were cement-free prostheses in the majority of cases. Our sample ultimately included only 3 cemented cups and 5 cemented femoral stems. The patients were all positioned in a lateral decubitus. The problems of the length of the neck and lateralization are resolved during the operation because all the prostheses are modular, and we have trial implants of all sizes, allowing us to do all possible tests before releasing the final implant. Stability and the length of the limb were clinically controlled on a table during the surgery before the final implants were placed.

- **Post-operative verification**

The values of the implants placed during surgery were recorded in the operating protocols. This allowed us to make the comparison between the sizes of the implants pre- and post-surgery.

The results, size for size and up to one size, were considered consistent in this study.

An X-ray of the postoperative internal rotation pelvis, enlarged to 115%, allowed us to calculate the postoperative femoral offset and compare it with the standards described in the literature.

The non-performance of post-operative scans by all patients (due to cost reasons) did not allow us to compare the positioning of our implants, as well as the pre- and post-operative femoral offset, and the planned and final cutting levels. Even though our control X-rays were at the same magnification as our scanners, a comparison of X-ray measurements and CT scans did not seem reliable.

Length inequalities were clinically measured and compared to pre-operative values.

- **Main measured values**

The measured values are stem size concordance, cup size concordance, pre- and post-operative limb length inequality, average pre- and post-operative limb length inequality, and postoperative mean offset of patients.

3. Results

- **Femoral stem**

The planning of the femoral stem was consistent with the definitive implant in 36 cases, or 69.2% ($P < 0.05$).

- **Cotyloid cup**

The planning of the acetabulum was consistent with the final implant in 43 cases, or 82.7% ($P < 0.05$).

- **Femoral stem and cup**

In 30 cases, or 69.8%, the forecasts were consistent for both the final femoral stem and the final cotyloid cup ($P < 0.05$).

- **Inequalities in length**

94.4% (49) of our patients had postoperative limb length equalization within 5 mm.

The initial length inequality, which varied from −35 to 50 mm with an average of 11 mm (DS = 25 mm), was post-operatively from −10 to 30 mm with an average of 9.6 mm (DS = 14 mm). The average improvement is 1.4 mm.

- **Femoral offset (X-ray)**

The postoperative mean femoral offset was 50.8 mm [33 - 69 mm] with a DS = 67 mm.

4. Discussion

Our study contains some biases that should be emphasized before any analysis, notably: our small sample of 52 patients, the consideration of a center of rotation of the hip corresponding to that of the laboratories, therefore approximate, the multiplicity of operators, and the multiplicity of implant brands used.

The biases related to the multiplicity of operators are due to the fact that the appreciation of stability, as well as the anteversion of the stem and the cup, is variable from one surgeon to another. Each surgeon has his own tricks that he deems reproducible and easy to perform during the operation each time (comparison of the equality of the two knees and heels placed side by side, identification of a landmark in relation to the greater trochanter, etc.).

As for the variability of cupule and stem prostheses, the design philosophy and designs are more or less different from one laboratory to another. Some will focus on the ease of installation of the implant, and others on the finish...

Planning for femoral stem size was consistent with the final implant within one size in 69.2% of cases ($P < 0.05$). This is in agreement with most authors, such as Gonzalez Della Valle *et al.*, The *et al.*, Scheerlinck, May, and Verhaeghe, for whom stem compliance varied between 30 and 84% for all methods combined [2] [5] [12]-[14].

The planning of the cup size was consistent with the cup set in 82.7% of cases to one size ($P < 0.05$). This is superior to some authors such as Gonzalez Della Valle *et al.*, Knight *et al.*, The et Coll., who found between 16% and 65% for the uncemented cupulas [2] [12] [13]. For the cemented cupulas, the authors report between 88% and 98% [1]. For all types of fixation combined, the average is 67% in the literature [1] [12]-[15]. With the contribution of 3D planning coupled with artificial intelligence, the results go up to 84% at more or less one size ($P < 0.05$) in XIE and 87% in Mainard *et al.* ($P = 0.30$) [14] [16].

Our results and methodology are more similar to those of May and Verhaeghe, who found in a series of 58 cases, with a 3D reconstruction CT support planning system, a compliance of 76.36% for the stem size and 83.64% for the size of the cup. In a study comparing the accuracy of 3D and 2D planning, Mainard *et al.* found a better accuracy in favor of 3D at more or less a size of the femoral stem at 83% vs 68% and 92% vs 87% for the cup.

As in our study, CT-based planning seems to be more reproducible regarding the size of the implants and especially the size of the acetabulum [17]-[19]. Indeed, with the coronal sections passing through the middle of the joint, one can see more or less clearly the contours of the original acetabular cup, even in the case of significant bone remodelling, as well as the true limits of the medullary. This allows the templates to be superimposed well.

94.4% of our patients had an equalization of the length of the limbs to 5 mm. These results are similar to those of Maloney *et al.* (82%) and Debarge *et al.* (85%) [3] [4].

The average improvement in limb length was 1.4 mm, a result almost similar to that of Debarge *et al.* (2 mm), but lower than that of Maloney (5.6 mm) and that of Aaron and al. (3.4 mm).

The postoperative mean femoral offset of our patients measured radiographically was 50.8 mm [33 - 69 mm]. This average seems higher than those found by the anatomical studies of Davey *et al.* (43.9 mm [22 - 57 mm]) and radiographs by Rubin *et al.* (39.7 mm [25 - 60 mm]), and scannographs by Lecerf: 45.8 mm [31 - 56 mm]. However, whatever the method of measurement, we have remained within the standards between 22 and 60 mm [18]-[20], and this seems compatible with human life.

The margin of error for femoral offset to 5 mm varies according to the authors between 27% and 30% [19]. The absence of a post-operative scanner in our study did not allow us to quantify this variable. Indeed, many authors are unanimous in the fact that there are factors that can modify femoral offset. According to Lecerf *et al.*, these include, among others, the radiographic enlargement, the rotation of the greater trochanter, which is not always visible on the images, and the comparison of this value between a pathological hip X-ray and an already operated hip X-ray. The pathological hip, prone to pain, stiffness, osteoarticular and muscular rearrangements (abductor muscles), is generally under the influence of a vicious position that the radiographer cannot fully control during the production of images, regardless of the precautions taken.

Most planning methods encountered in the literature used either a conventional hip X-ray with enlargements ranging from 110% to 120%, a digital hip X-ray, or CT images. Even though CT images were used in some studies, they were small in size and only suitable for computer screens. They were coupled with adapted software whose installation was costly for hospitals. The hospital in Carcassonne does not yet have this planning computer tool, so the surgeons and radiologists at this hospital tried to adapt their working methods more or less to standards. Thus, in our study, the CT images were enlarged to 115%, like the conventional X-rays previously used and known by all orthopedists.

The interest of this method lies mainly in the possibility of coronal and sagittal cuts that better account for the morphology of the different anatomical bone landmarks (trochanters, neck, femoral head, acetabulum, radiological U). With this method, we get closer to a 3D observation than to a 2D one. There are clearly still shortcomings.

To overcome these shortcomings related to the types of enlargement used, more advanced methods now exist that allow 3D planning [14] [21], or even 3D-artificial intelligence coupling [16] [22], whose results are better, with an overall accuracy varying between 84% and 95.1%, whereas the 2D methods have an overall accuracy of 64% to 81.1%.

5. Conclusion

Planning using high magnification CT images (115%) is a reproducible planning method for implant size. It seems more precise for the size of the acetabulum without being less precise than other methods regarding the size of the femoral stem, as well as the equalization of the length of the limbs. When this method is well mastered, it could be an unboxing method when computerized planning software associated with computed tomography is not available.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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