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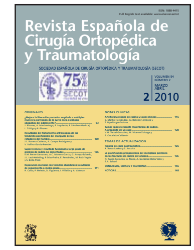

REVIEW ARTICLE

Preoperative planning of prosthetic replacement in hip fractures in the elderly

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KEYWORDS
Hip fracture;
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Abstract
There are numerous reports on successful results for total hip replacement being achieved through preoperative planning. However, none of these reports have been focused on the treatment of hip fractures. Preoperative planning has increased importance in this group of patients as the correct biomechanical reconstruction of the hip is made more difficult by the absence of an intact femur.
This report describes a method for preoperative planning based on the reproduction of the biomechanics of the intact contralateral hip, if and when it is anatomically normal. The plan is based on radiological measurements that are reproduced during surgery to achieve normal biomechanical reconstruction for the fractured hip.

PALABRAS CLAVE
Fractura de cadera;
Artroplastia de cadera;
Planificación preoperatoria

La planificación preoperatoria del reemplazo protésico en las fracturas de cadera del anciano

Resumen
Existen numerosas publicaciones sobre la planificación preoperatoria en los reemplazos de cadera electivos con resultados satisfactorios. Sin embargo, ninguna de ellas se ha enfocado para el tratamiento de las fracturas de cadera. La planificación aumenta su importancia en estos pacientes debido a que la reconstrucción de la biomecánica de la cadera se ve dificultada por la ausencia de un fémur intacto.
En este trabajo se describe un método de planificación preoperatoria basado en la reproducción de la biomecánica de la cadera contralateral no fracturada, siempre y cuando

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ésta sea anatómicamente normal. El plan registra medidas radiológicas que se reproducen durante la cirugía para lograr una reconstrucción de la biomecánica normal de la cadera fracturada.

Introduction

The past two decades have seen a significant rise in the incidence of hip fractures in the elderly population. Among other factors, the rise is a result of the growing population and increasing life expectancy.[1-3] Due to increasing frequency and the high morbidity and mortality rates, in addition to the significant financial burdens arising from their treatment and sequelae, hip fractures in the elderly are a serious problem not only from the patient's point of view, but also from societal and public health standpoints.[4]

Among hip fractures, the displaced femoral neck fracture (Garden III-IV) is often called an "unsolved fracture", because its treatment remains controversial[5] to this day. The two available therapeutic options are reduction and fixation of the fracture with preservation of the femoral head and the total or partial hip replacement.

In the latest Cochrane review[6] on the treatment of femoral neck fractures in adults, 17 randomised controlled trials involving 2694 patients with 2697 fractures were analysed. Internal fixation of intracapsular hip fractures showed a significant decrease in operative time (average of 28 minutes shorter), blood loss, the need for blood transfusion, and the risk of deep infection, when compared with hip arthroplasty. However, the likelihood of needing a reoperation was higher after surgical internal fixation than after hip arthroplasty (36% versus 11%). The main published causes of failure of internal fixation were the presence of non-union of fractures in 28% of cases (20-35%) and avascular necrosis of the femoral head, which occurred in 9.7% of patients (5-30%). This meta-analysis[6] showed no statistically significant differences between the two methods in regards to the length of hospital stay, the occurrence of postoperative medical complications, patients' post-operative return to the place of pre-operative residence, or mortality one year after surgery.

More recently, in a meta-analysis of treatment methods for intracapsular fracture performed by Rogmark and Johnell in 2006,[7] it was shown that fewer serious complications occurred secondary to surgery (infections, reoperations), functional outcomes were better, and patients reported less pain after hip replacement than after internal fixation. This meta-analysis showed reoperation rates of 14-53% after internal fixation versus a rate of 7% after hip arthroplasty.

The choice of treatment modality depends on the patient's physiological age, which is determined by their previous walking ability, mental state, and associated comorbidities. In order to determine the physiological age, specific scales have been described;[8] however, a careful assessment of the patient, based on these parameters will help the surgeon decide on the most appropriate treatment on an individual basis.

Briefly, in a healthy and active young patient (physiological age under 65 years, able to undergo a new surgery) every effort should be made to preserve the femoral head. The treatment of choice in this case is reduction and internal fixation of the fracture. Patients in this group have also shown higher rates of mineralisation compared to older patients, possibly due to better bone quality and increased mineralisation capacity. If osteosynthesis fails, total hip arthroplasty (THA) is indicated as rescue therapy.

On the contrary, hip joint replacement is recommended in patients with physiological age above 65 years. This is due to the longer periods of deconditioning and the greater risk of requiring reoperation in this patient group. In addition, joint replacement is indicated in cases in which poor bone quality increases the risk of failure of osteosynthesis, such as with pathologic fractures due to metastasis, irradiation, renal osteodystrophy, Paget's disease or hypothyroidism. Other indications for arthroplasty are Parkinson's disease and spastic hemiplegia, due to functional reasons (incapacity from deconditioning).

Currently, research[9,10] is focused on the comparison between results obtained with hemiarthroplasty (HA) and THA for the treatment of femoral neck fractures. These studies have shown no statistically significant differences when comparing short and long term mortality rates after both types of arthroplasty.[10,11]

HA of the hip has been characterised as a less complex surgical procedure, with fewer complications, shorter surgical time (58.5 minutes [HA] versus 82.4 minutes [THA]) and lower overall cost compared to THA. However, since the femoral head prosthesis has an erosive effect on the acetabulum after HA, in the long-term,[11] those patients who have had HA eventually present with increased pain, decreased mobility (walking distance: 1.9km [HA] versus 3.6km [THA]) and increased risk of requiring surgical revision than after a total hip arthroplasty. Therefore, by comparing the total cost of these procedures, including the price of the initial surgery and subsequent complications and reoperations, a lower overall cost has been shown with the use of THA.[12]

The choice of the type of arthroplasty depends primarily on the patient's age, overall health, and previous ability to ambulate.

In active patients (greater functional demand) with physiological age older than 65 years and with a life expectancy greater than 5 years, a THA is recommended.[13] This is also the procedure of choice in patients with rheumatoid arthritis or coxarthrosis in which there is a femoral neck fracture.

In elderly patients with low functional demands (poorly ambulatory institutionalised or limited ambulatory, non-institutionalised patients) and life expectancy less than 5 years,[13] a cemented hip HA is recommended.[10] The use of a bipolar HA aims to diminish the painful erosive effect of the femoral head on the acetabular socket, but its superiority over monopolar HA has not yet been definitively proven.[14,15]

One concern about the performance of hip arthroplasty in elderly patients with displaced femoral neck fractures is the increased risk of prosthetic dislocation (6-22% versus 4-10%) and periprosthetic fracture compared with hip arthroplasty performed in patients with primary coxarthrosis.[16-18]

The increased risk of prosthetic dislocation in this group of patients is due to their greater age, cognitive impairment, neuromuscular deficits, laxity and risk of falls, compared with the population of primary coxarthrosis. However, proper positioning and orientation of prosthetic components (especially the acetabulum) can reduce the incidence of dislocations.[19]

There are numerous publications that demonstrate the benefits of planning before surgery in elective hip replacements.[20,21] However, none of these have focused on the treatment of hip fractures. In these patients, restoration of the biomechanics of the hip is more complex because the surgeon does not have an intact femur to guide the reconstruction of the offset and length of the fractured limb.

The aim of this paper is to provide a detailed description of a preoperative planning technique, adapted to the treatment of hip fractures, which achieves greater accuracy in the position and orientation of prosthetic components. This technique is based on the replication of the biomechanics of the healthy contralateral hip (not fractured) and to allow for accurate reproduction of the orientation and position of components using reference measurements.[22,23]

History and physical examination

A detailed history and physical examination help to decide the type of arthroplasty (total or partial), method of fixation, and implant design most appropriate for the patient. It is essential to know the patient's age, concomitant diseases, regular medications, surgical history, presence and degree of cognitive impairment, activity level prior to fracture, involvement of other nearby joints and life expectancy.

The preoperative planning method described in this work is based on the replication of the biomechanics of the contralateral hip (not fractured). For this reason, it is essential to perform a careful physical examination of the hip to rule out any congenital or acquired diseases that may affect planning. In addition, the patient should be questioned about the presence of gait changes and limb dysmetria prior to the fracture.

In those patients with increased risk of prosthetic dislocation[24] (octogenarian patients with major cognitive impairment or with neuromuscular diseases) prosthetic heads of larger diameter[25] or HA may be used. In patients with poor bone quality it is preferable to use cemented femoral fixation, and those with increased risk of infection (diabetics, immunocompromised patients) antibiotics in cement may be used.

Radiographic studies

Radiographs must be of good quality, obtained in a particular position and with a known magnification. If one or more of these important requirements are not met, the preoperative plan will be imprecise. In fracture patients, good pain control facilitates the execution of adequate imaging studies.

In most patients, planning can be done based on an anteroposterior (AP) pelvis radiograph centred on the pubic symphysis in which 15 to 17 cm of femoral diaphysis can be observed.

The patient should be placed in a supine decubitus position with the healthy hip at 15° of internal rotation (pure AP of the femur). This position neutralises physiologic anteversion of the femoral neck and allows the true offset of the healthy hip to be observed.

The magnification of the radiographs and of the prosthetic implant templates must be equal. For a magnification of approximately 20 ± 6% [2 SD],[6] the ray focal point is located 1m from the radiation table and the radiographic plate is placed 5cm below the table (slot x-ray table), with a total distance between the ray source and the plate being 115-120 cm.

Prior to making the template, the radiographic quality and the position of the visible structures must be carefully examined. The radiographic quality should allow the surgeon to visualise the cortical and trabecular bone structures of the pelvis and femur in detail. Bone density at the acetabulum and femur[27] guides the choice of implant fixation system (cementation of the femoral stem, using screws in the acetabular component). Moreover, the study of the trabecular structure of the fractured femoral neck accompanied by a detailed history can help to predict the existence of a pathologic fracture, with consequent therapeutic and prognostic implications.

In a strict anteroposterior radiograph, the centre of the sacrum, the coccyx and the pubic symphysis are aligned, and the images of the obturator foramina are symmetrical. This is not true of radiographs with pelvic rotation and generates errors in the template. If the ray tube is not oriented correctly or the patient has a flexion contracture or severe pelvic obliquity, the obtained radiographic image can be inlet type, with the consequent distortion of the bony structures hindering template completion. At the femoral level, visualisation of the lesser trochanter helps determine the degree of hip rotation. If the image of the normal hip is not obtained in 15-20° of internal rotation, the calculated offset will be lower than the actual measurement and will introduce error in the planning, thus altering the biomechanics of the hip.

Templates

The template method for the treatment of femoral neck fractures that require total joint replacement is described first and then a short section concerning HA templates follows.

Component templates must use a magnification similar to that obtained in radiographic images. Commercial entities assume a fixed amplification for Spanish individuals of around 15-20%, and in general, supplied templates take this amplification into account.

One must methodically document information obtained during the templating process. This documentation includes in chronological order (first the femur and second the acetabulum) the design, type and size of implants that will be used and measurements to make during surgery in order to reproduce the plan intraoperatively. To facilitate and expedite the surgery, the entire surgical team should be familiar with the meaning of these annotations (table).

Acetabular component templates

The acetabular template begins with the delineation of a horizontal reference line to determine the correct inclination of the acetabular component. In the majority of cases, this line can be drawn through the lower corners of both teardrop images[28] (fig. 1). If the teardrop images are not clearly visible, the corners below the sacroiliac joints can be used. The lower corners of the ischial tuberosities are often distorted by pelvic rotations, previous fractures or anatomical variations.

If both acetabular cups have similar shape and size, the acetabular component templates can be made in the cup of the unfractured hip. The plan starts by identifying the superolateral acetabular rim, the ilioischial line and the teardrop image. Visualisation of the anterior and posterior margins of the acetabulum can guide the surgeon in determining the correct acetabular anteversion during surgery.

Subsequently the position and size of the acetabular component are determined using the template with appropriate magnification. By superimposing the acetabular component templates, the correct size that meets the following conditions is sought: a cup, when at approximately

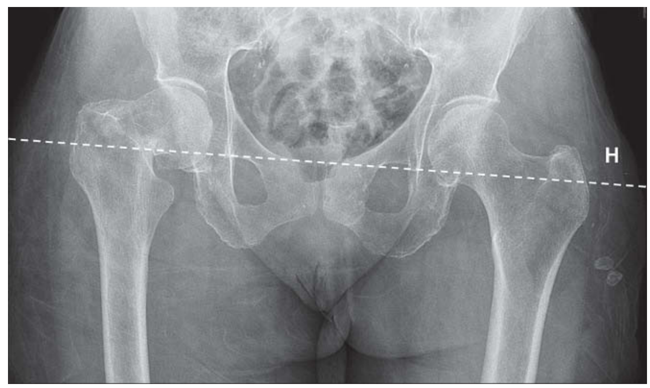

Figure 1 Anteroposterior pelvic radiograph of an 82-year-old patient with a subcapital fracture of the right femur. Planning started by tracing the horizontal (H) pelvic reference line drawn between the two teardrop images.

Table

Areas	Description	Example
1. Acetabular component	—Design and size of the acetabular component —Distance between teardrop image and inferomedial edge of acetabular component (subscript) —Distance between the apex of the cup and the uppermost acetabular rim (superscript)	ACETABULAR CUP 50^{5}_{10}
2. Acetabular Insert	—Design and femoral head diameter	INSERT 32 not constrained/ Cross-linked
3. Femoral component	—Design, size and offset of the femoral component	STEM $_{EXT}$ 1 .
4. Prosthetic femoral head	—Diameter of the prosthetic femoral head —Length of neck	32+0
5. Reference distance	1) Between **TI** ** the level of femoral neck osteotomy 2) Between the medial osteotomy and stem 3) From **TI** ** and the centre of rotation of the femoral head	$15_{(1)}$ $12_{(2)}$ $50_{(3)}$
6. Centralisor or restrictor (optional)	—Diameter of Ct —Diameter of Tp or cement plug	Ct: 11/Tp: 22

Ct: centralisor; TI: lesser trochanter; Tp: restrictor.

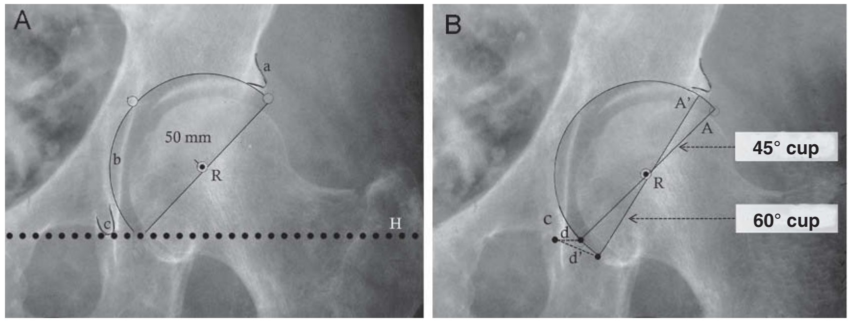

Figure 2 Template of acetabular component. A) The image shows an acetabular component of appropriate size and position. B) The image shows the usefulness of the distance (d) between the inferomedial edge of the acetabular component and the lower corners of the teardrop images in precisely determining acetabular angle. The distance (d) in a cup with the correct angle (45°) increases at a distance (d') by increasing the angle of the acetabular component (A' to 60° of inclination). Moreover, increasing the inclination of the acetabular cup reduces the lateral cup's coverage, which is reflected in the shortest distance between the apex of the cup and the superolateral acetabular rim. a: superolateral acetabular rim; A: acetabular component with correct inclination, A': acetabular component in more vertical position; b: ilioischial line; c: teardrop image; d: distance of the correct acetabular component; d': distance from the vertical acetabular component; e: distance between the apex of the acetabular cup and the superolateral rim; H: horizontal reference line; R: centre of rotation of the acetabular component.

45° abduction, the medial border of which is approximately at the ilioischial line, with inferior edge approximately at the horizontal inter-teardrop reference line, while obtaining the maximum coverage with minimal removal of sclerotic subchondral bone (fig. 2A). After selecting the size and position of the acetabular component, the centre of rotation and the profile of the cup are marked on the radiograph.

To successfully reproduce the inclination of the acetabular component intraoperatively, two radiological measurements should be taken with a magnified ruler. The first is the distance between the lower corner of the acetabular cup and the teardrop image (fig. 2B). This distance is usually short (5-10 mm) and very sensitive to changes of inclination of the cup. The second measurement is the distance between the apex of the acetabular cup and the superolateral acetabular rim.

Finally, in the first line of the operative note the type and size of the acetabular component must be recorded, together with the two measurements described above as subscript and superscript (table). In the second line the characteristics of the acetabular insert (the insert material, prosthetic head diameter) are recorded.

If there are anatomical differences between the two acetabular cups, it is necessary to make templates with both the healthy cup and the fractured cup and to make sure both are of the same height. Otherwise, the surgeon must make the necessary adjustments in the height of the femoral component to equalise limb length.

In bipolar arthroplasty, the acetabular component template is replaced by that of the bipolar cup. The outside diameter of the cup should be slightly greater than the diameter of the femoral head bone (fig. 3). After the centre of rotation of the bipolar cup is marked, femoral templating proceeds. Often, when performing an HA, the centre of rotation is slightly more caudal and lateral than with a total replacement.

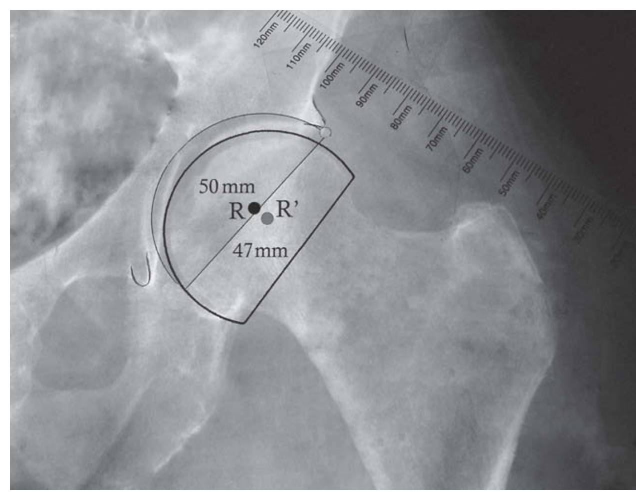

Figure 3 Template of bipolar cup. The image shows the most caudal and lateral position of the bipolar cup's centre of rotation compared to the centre of rotation of the acetabular component. Also shown is the smaller diameter of the bipolar cup (47 mm) compared with the acetabular component (50 mm). R: centre of rotation of the acetabular component, R': centre of rotation of bipolar cup.

Template of the femoral component

The objectives of the femoral component templates are to obtain proper fixation and alignment of the femoral stem within the channel, the restoration of offset and limb length.

In most patients with hip fractures, there is no preoperative discrepancy in limb length. If the patient has pre-fracture asymmetry in which the fractured limb was shorter than the healthy, the surgeon may choose to lengthen the limb during the surgery. However, if the previously fractured limb was longer than the healthy one,

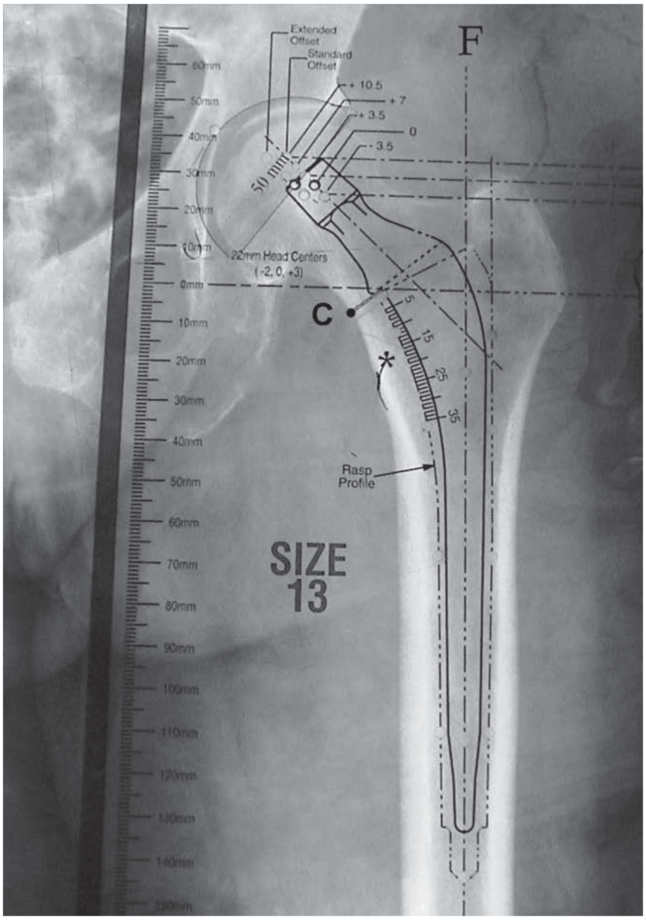

Figure 4 Image showing the correct template of a femoral component in which the rod axis is aligned with the axis of the femoral shaft (F) and whose size allows for a homogeneous circumferential cement mantle and (marked line points) in the femoral shaft. *: Proximal lesser trochanter; C: area of choice for femoral neck osteotomy; F: femoral shaft axis.

it is important to inform the patient that the asymmetry may persist after prosthetic replacement because intentional shortening of the fractured limb may result in undesirable prosthetic instability.

The fractured limb length is determined by the level of insertion of the femoral stem and the length of the prosthetic head.

To select the correct size of the femoral stem, the femoral component template is superimposed over the affected limb to select one whose axis aligns with the axis of the femoral shaft and the shaft which best fits the proximal femoral metaphysis and intramedullary canal (internal walls of the femur). Given the high incidence of osteoporosis in elderly patients with hip fractures, we prefer to use cemented fixation of the femoral stem, so that the selected size allows for a homogeneous, circumferential cement mantle of about 2 mm in thickness (usually marked on the template with dashed line) (fig. 4).

After determining the size of the femoral stem, one should choose the offset of the femoral component whose centre of rotation is closest to the horizontal acetabular centre of rotation (normal offset, extended offset). If the centre of rotation of the femoral head lies medial to the centre of rotation of the acetabular cup, the offset increases. Conversely, the offset is reduced if the centre of rotation of the femoral head is lateral to the centre of rotation of the acetabular cup.

Subsequently, the template is slightly displaced within the femoral axis until reaching the correct femoral neck girth (the selected offset is maintained) with which the vertical maximum of the femoral and acetabular centre of rotation is approximated. The surgeon should try to use prosthetic heads that do not reveal the Morse taper or that do not have sheaths that create an unfavourable neck-head ratio.

After determining the size, offset, neck length and level of implantation of the femoral component, the profile should be drawn on the radiograph of the pelvis and the level of femoral osteotomy and femoral centre of rotation should be highlighted. In the third line of the operative note, the surgical design, size and the offset of the femoral stem is recorded. The femoral head diameter and length of the prosthetic neck is recorded in the fourth line of the note (table).

To intraoperatively reproduce the position of the femoral stem and determine the level of neck osteotomy, three measurements should be recorded using the magnified ruler, usually found in the selected template magnification (fig. 5A). The first is the distance between the proximal apex of the lesser trochanter and the area medial to the cervical osteotomy. This measurement is essential to determine the level of cervical osteotomy intraoperatively. The second measurement is the distance between the proximal apex of the lesser trochanter and the centre of rotation of the selected prosthetic femoral head. This measurement is key to reproducing the chosen offset and limb length. Finally, the distance between the most medial aspect of the femoral neck and the femoral stem implantation site at the top of the cervical osteotomy must be measured. This third measure is essential to avoid a varus- or valgus-positioned stem.

Another measurement that can be used is the vertical distance between the centre of rotation of the femoral head and the tip of the greater trochanter, as an additional reference to ensure correct positioning of the centre of rotation of femoral stem. These measurements are recorded in the operative note (table). If necessary, you can also mark the diameter of distal stem centralisor and cement restrictor plug.

The lateral hip radiograph can be used to plan the correct point of entry for the femoral stem at the AP level using the lateral femoral template.

Implementation of the plan

Meticulously reproducing the measurements in the operative note during surgery increases surgical precision during

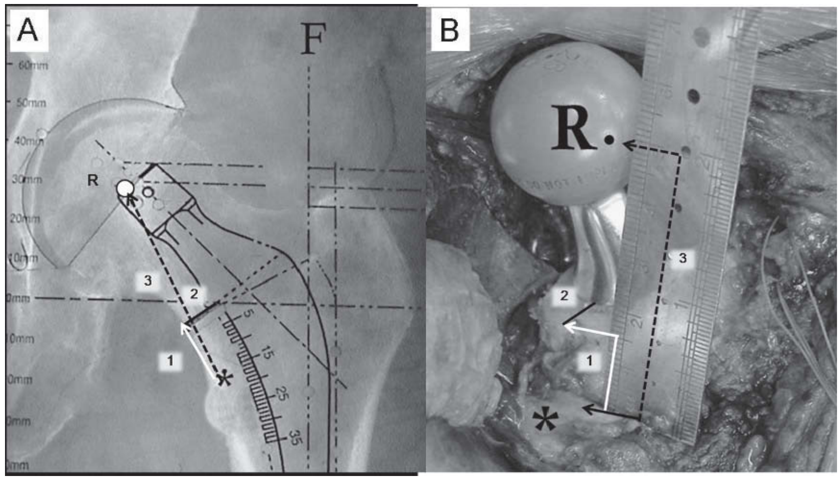

Figure 5 A) This radiograph shows how to calculate the reference distances for femoral component planning. 1: distance between the superior corner of the lesser trochanter and femoral neck osteotomy site; 2: distance between the medial femoral osteotomy and stem; 3: distance between the upper corner of the lesser trochanter and the centre of rotation of the prosthetic head. B) Intraoperative image showing how to reproduce the baseline radiographic measurements of the patient's femur, after insertion of trial components. Following the identification of the femoral head centre of rotation, the proximal angle of the lesser trochanter and the medial border of cervical osteotomy, a sterile ruler is used to calculate the distances previously described (6A). *: Proximal lesser trochanter; F: femoral shaft axis; A: centre of rotation of the prosthetic head.

placement of the selected components. Therefore it is imperative to have a sterile marker and a millimetre ruler during the surgical procedure.

The appropriate positioning of the pelvis on the operating table reduces the variability in the orientation of the acetabular component. After the surgical approach, the proximal angle of the lesser trochanter is located and the planned length of the osteotomy is marked (fig. 5A). Sometimes the fracture line may be below the level of the planned cervical osteotomy. In these cases, the surgeon must make the necessary modifications to the surgical technique or to the implant in order to replicate the distance between the lesser trochanter and the femoral centre of rotation.

The acetabular component must be between 40-50° of abduction[29] and 15 ± 10° of anteversion, and the acetabular component size guides the cup milling. To accurately reproduce the orientation of the acetabular component, the reference measurements recorded in the surgical note are used. One must use a fine graphing tool marked in millimetres to calculate these measurements of the depth and width of the area. After placement of the test acetabular component in the proper position, the teardrop shape (inferomedial edge of the acetabular wall) is palpated with the fine instrument and the distance between this point and the lower edge of the acetabular component is measured.

If this measurement is greater than that recorded during planning, it indicates that the acetabular component is too vertical[30] and it will be possible to correct its position (fig. 2B). Conversely, if the measurement is smaller than planned, it indicates that the acetabular component is too horizontal. Reproduction of the distance between the apex of the cup and the superolateral margin of the acetabulum (lateral

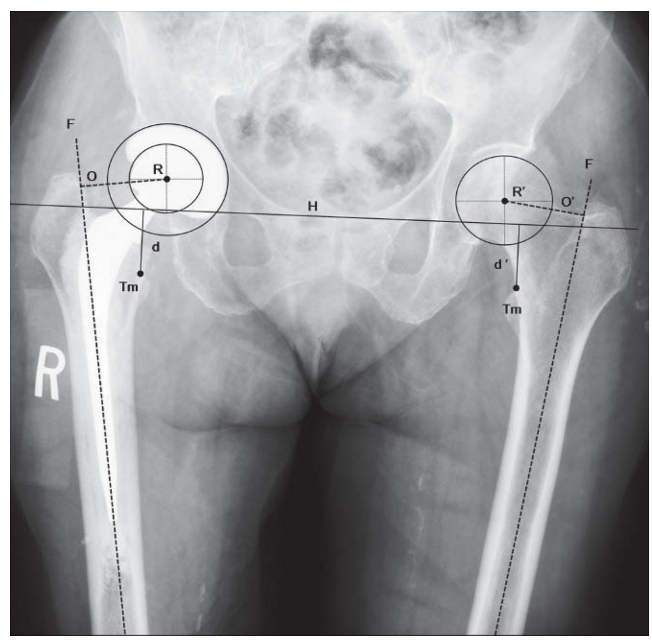

Figure 6 Anteroposterior pelvis radiograph showing a total hip arthroplasty (same patient from fig. 1) performed after completion of preoperative planning (table 1). It confirms the correct positioning of the components and anatomical restoration of the biomechanics of the fractured hip (centre of rotation, offset [O = O'] and limb length [d = d']). d: vertical distance from the reference line to the proximal angle of the lesser trochanter; d': normal distance; F: femoral shaft axis; H: horizontal reference line between the two teardrop images; O: offset of the operated hip; O': normal offset; R: centre of rotation of the arthroplasty; R': hip's normal centre of rotation; Tl: lesser trochanter.

coverage) will confirm the proper inclination of the component.

During femoral milling, the surgeon must be guided by the annotations of the plan (size) and by tactile sensation.

Once the test femoral stem has been placed for the chosen size, offset and neck length, one must measure the distance between the apex of the lesser trochanter and the centre of rotation of the femoral head (marked with marker) (fig. 5B). If this distance does not match the plan, the necessary adjustments should be made (offset, neck length and stem height) intraoperatively.

Finally, the hip prosthesis is reduced with the test stem and head, and its stability, the balance of the soft tissues and its complete range of motion are checked. After this test, the surgeon confirms the definitive femoral components or makes the necessary adjustments for prosthetic stability and mobility.

The postoperative radiographs are checked for correct positioning and fixation of implants. One must also confirm the proper restoration of the biomechanics of the fractured hip, compared with the contralateral hip, which has been used as a guide to reconstruction (fig. 6).

Discussion

There are numerous publications on surgical planning in elective hip replacements with satisfactory results.[20,21,31] However, none have focused on any of these techniques for the treatment of hip fractures.

In these patients, restoration of the biomechanics of the hip is more complex because the surgeon does not have an intact femur to guide the reconstruction of the offset and length of the fractured limb. The increased physiological offset prevents the surgeon from performing an adequate repair of the capsular, tendinous, and muscular structures that were damaged during the trauma or the surgical approach, and which endanger the prosthetic joint's stability.[32] In parallel, this increased offset may generate contractures in abduction and internal rotation with consequent alteration of gait. The decreased offset or shortening of the limb increases the risk of instability and gait claudication.[33,34] Finally, if a limb is excessively elongated, it may cause contractures and gait changes and may be grounds for litigation.[35] To restore the biomechanics of the fractured hip, the planning is based on the replication of the healthy contralateral hip (not fractured).

Another feature of this planning technique is the use of reference points and measurements that are easily identifiable on radiograph and intraoperatively. By using this technique, the position and orientation of the previously planned components may be reproduced with precision.

The teardrop images are used to orient the acetabular component, since this anatomical reference point is one of the most accurate and steady of the pelvis.[28] The teardrop image represents the inferomedial edge of the acetabular wall, its outer surface corresponds to the acetabular background (the deepest and most inferior zone of the acetabulum) and its inner surface corresponds to the medial acetabular wall. In planning the femoral component, one uses the superior angle of the lesser trochanter as a reference point which facilitates intraoperative location of the midpoint, which is used in other planning techniques.[31]

By using this method in elective hip arthroplasty and fracture repair, we have been able to reproduce the centre of rotation of the hip prostheses ± 4mm in 93.5% of cases.[22] The asymmetry of limbs after joint replacement in fractures using this method was 3.27mm (range: –3 to 8mm). Seventy-seven point three percent of patients presented with asymmetry less than or equal to 5mm after hip fracture surgery. This is a higher percentage of asymmetry in comparison to the population with coxarthrosis (87.3-86% with asymmetry ≤ 5mm). This difference is due to the fact that in patients with hip fractures it is not possible to determine the presence of limb asymmetry in advance and therefore not possible to accurately compensate for these discrepancies using arthroplasty.

We have not studied the reduction in the prosthetic dislocation rate directly; however, we have shown an improvement in the accuracy of acetabular component placement using this technique.[30] We obtained an acetabular component angle within the safe range (40 ± 10°) in 100% of cases and between 43.8° and 45.4° in 95%. Furthermore, the use of femoral reference measurements has provided a neutral femoral stem alignment in 87.7% of patients, varus (< 4°) in 8% and valgus (< 2°) 4%.

Another advantage of using this method of planning is identifying the design and size of implants before surgery. The correct acetabular and femoral component size ± 1 was used in 97.4% of cases. These data can reduce surgical time since the team knows what the surgical note means and is able to prepare the implants beforehand.

Other authors with similar planning techniques have managed to successfully predict the size of acetabular implants between 62-90% of the time and cemented femoral components between 78-92% of the time.[28,29]

It is advantageous to use this method because one can foresee potential complications that may occur during surgery. Some of these possible complications include the need for bone grafts in areas with large defects, cement in cases of poor bone quality, avoiding false passage periprosthetic femoral fractures by planning the proper orientation of the femoral canal milling, etc.

The presence of a contralateral hip that is abnormal, arthritic, or that has congenital deformities (dysplasias) or acquired deformities (posttraumatic) limits the use of this technique. However, in cases where the contralateral hip had been replaced previously and its biomechanics are adequate, the surgeon can use the replaced hip as a reference template for the fractured hip.

Proper planning of position and prediction of the component size may be affected by many factors that must be known in order to minimise the risk of error. Magnification markers can be used systematically to reduce the risk of magnification error. A team of trained radiology technicians must perform the radiographs. Body habitus of patients can affect the magnification, which is slightly lower in very thin patients (15%) and slightly higher in obese patients (25%). Knowledge of this detail will allow for the necessary adjustments to increase the plan's accuracy. Incorrect magnification will affect the correlation between radiological and intraoperative measurements. The measurement that is most likely to be affected by these variations is the longest one (distance between the lesser trochanter and the centre of hip rotation).

Currently, most hospitals use digital radiological images, which have increased interest in digital over analogue planning.[21,37] The basics of the planning method that we described can be adapted to digital planning and, with the subsequent acquisition of a known magnification, will increase the precision of this technique.

In conclusion, we believe that this method of preoperative planning is simple and reproducible and allows for proper component orientation and restores the biomechanics of the fractured hip during hip replacement.

Conflict of interest

The authors declare that they have no conflicts of interest.

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