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REVIEW ARTICLE

Femoral offset: Anatomical concept, definition, assessment, implications for preoperative templating and hip arthroplasty

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KEYWORDS
Hip;
Offset;
Center of rotation;
Total-hip arthroplasty;

Summary
Background objective. — Femoral offset is supposed to influence the results of hip replacement but little is known about the accurate method of measure and the true effect of offset modifications.
Material and methods. — This article is a collection of independent anatomic, radiological and clinical works, which purpose is to assess knowledge of the implications of femoral offset for preoperative templating and total hip arthroplasty.

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Templating;
Computer-assisted surgery

Results. — There is a strong correlation between femoral offset, abductors lever arm and hip abductor strength. Hip lateralization is independent of the femoral endomedullary characteristics. The abductors lever arm is highly correlated to the gluteus medius activation angle. There were correlations between femoral offset and endomedullary shape. The hip center was high and medial for stovepipe metaphysis while it was lower and lateralized for champagne — flute upper femur. A study was performed to compare the femoral offset measured by X-ray and CT-scan in 50 patients, demonstrated that plain radiography underestimates offset measurement. The 2D templating cannot appreciate the rotation of the lower limb. Taking into account the horizontal plane is essential to obtain proper 3D planning of the femoral offset. A randomized study was designed to compare femoral offset measurements after hip resurfacing and total hip arthroplasty. This study underlined hip resurfacing reduced the femoral offset, while hip replacement increased offset. However, the reduction of femoral offset after hip resurfacing does not affect the function. A pilot study was designed to assess the results of 120 hip arthroplasties with a modular femoral neck. This study showed that the use of a modular collar ensures an easier restoration of the femoral offset. A cohort of high offset stems (Lubinus 117°) was retrospectively assessed. The survival rate was slightly lower that the standard design reported in the Swedish register. Finally, the measurement of offset and leg length was assessed with the help of computer assistance. The software changed the initial schedule (obtained by templating) in 29%.

Conclusion. — Therefore, femoral offset restoration is essential to improve function and longevity of hip arthroplasty. CT-scan is more accurate than plain radiography to assess femoral offset. Hip resurfacing decreases offset without effect on function. Modular neck and computer assistance may improve intraoperative calculation and reproduction of femoral offset. Increasing offset with a standard cemented design may decrease long-term fixation.

Level IV: Retrospective or historical series.

MOTS CLÉS
Hanche ;
Offset ;
Centre de rotation ;
Prothèse totale de hanche ;
Planification ;
Chirurgie assistée par ordinateur

Femoral offset: general remarks and definitions

Femoral offset is the distance from the center of rotation of the femoral head to a line bisecting the long axis of the femur (Fig. 1). This radiographic measurement should be accurately performed and varies according to the hip rotation. Offset (range, 41 to 44 mm) increases with the size of the femur showing a good correlation coefficient [1]. However, this notion is not sufficient to appropriately define proper hip anatomic landmarks. The abductor muscle lever arm, the gluteus medius activation angle, the cervico-cephalic angle as well as anteversion of the femoral neck should also be determined. The path of the abductor muscles might be represented by drawing a line tangential to the lateral margin of the greater trochanter. The abductor muscle lever arm is thus perpendicular to it (Fig. 1). The work of Mac Grory et al. [2] statistically demonstrates a significant statistical correlation between femoral offset and abductor muscle lever arm and strength. The femoral neck-shaft angle determines the size of the anatomical femoral offset [3]. It defines the features of each prosthetic stem and thus influences the neck and leg length. Femoral neck anteversion defines the ''physiological offset'': an increase in femoral neck anteversion results in back displacement of the greater trochanter and decreases the functional offset, the lever arm and the gluteus medius strength.

The hip center of rotation characterizes the femoral head-acetabulum couple. Lateralization of the hip center of rotation is measured relative to the radiographic ''U-landmark'', or relative to the pelvis median axis if radiographically possible. The height of the hip center is measured relative to the bi-ischiatic line or to the bottom of the radiographic ''U-landmark''. It determines the tension of the abductor muscles [4]. The global offset is the sum of the femoral offset and lateralization of the hip joint center of rotation. It determines the axis of activity of the abductor muscles (Fig. 1). Pauwels has shown that during a single-leg standing position, the body weight was counterbalanced by the abductor muscles strength [3]. The application point of the resultant force is situated at the hip joint center. Medialization of the hip center of rotation positively affects hip function as for abductor lever arm. Frain [5] has detailed

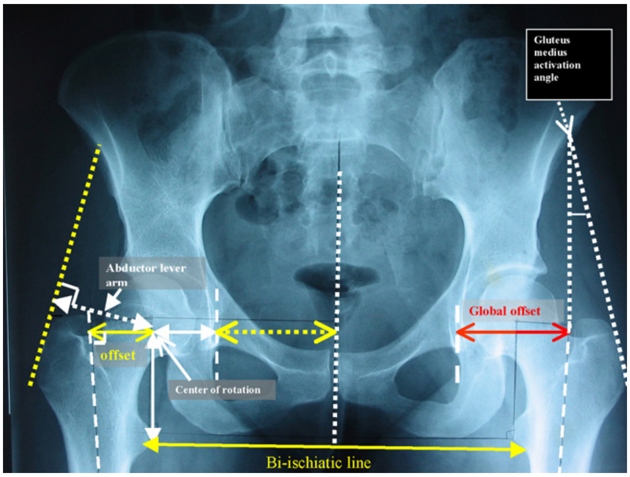

Figure 1 Radiographic measures of offset (femoral and global), abductor muscle lever arm and angle of abductor muscle activation.

this analysis by adding the direction of the abductor muscle axis. He defined the ilio-trochanterian angle: this angle is delimited by the line running from the center of rotation to the mean insertion point of the gluteus medius and the line running from the center of rotation to the tip of the greater trochanter. The strength of the abductor muscles varies according to the variations of this angle. Any variation in the center of rotation or offset influences the ilio-trochanterian angle and thus the force required by the gluteus medius to balance the pelvis (Fig. 2).

In case of a pathological hip, the surgeon can refer to the contralateral hip for preoperative planning, however according to Krishnan et al. [6], this method lacks accuracy. The Ranawat triangle or Kohler line might also be helpful landmarks. However, it would be advisable to use Pierchon's method which appears to be more reliable. [7]: a constant ratio has been observed between lateralization of the hip center of rotation and both radiographic ''U-landmark'' (0.30 in men, 0.25 in women). The same findings could be established regarding the height of the hip center of rotation relative to the downward sloping point of the radiographic U-landmark when referring to the height between the latter and the sacroiliac joint (0.20 in men, 0.18 in women).

Analysis of the femoral offset is quite recent in the literature. Besides some original reports [3,8,9,10], various publications appear to be of great interest. Previous studies have shown that increasing femoral offset will improve hip abductor strength [2,11], enhance range of motion [2,12], reduce limping and the need for crutches [8,13—15]. Offset restoration seems to decrease dislocation risks [2,3,16], cup strain and polyethylene wear [17—20]. Moreover, restoration of the hip center of rotation could decrease the incidence of failures and reduce the need for revision surgery.

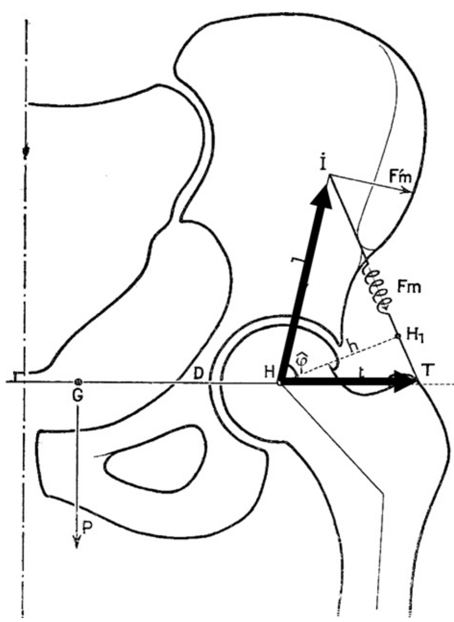

Figure 2 The ilio-trochanterian angle according to Frain [5] takes into account the morphologic features of the Femur and the Ilium for the region of insertion of abductor muscles.

Femoral lateralization: anatomical basis

Restoration of the abductor lever arm during arthroplasty, implies restitution of lateralization. Lateralization therefore appears as an essential parameter.

Material and methods

We carried out a radio-anatomical study based on AP pelvic radiographs performed in the standing position, the lower limb placed in internal rotation so the patella is situated in the frontal plane. One hundred and fifty patients of mean age 67 years were included in that study. All studied hips were healthy. Lateralization and extramedullary parameters were measured on pelvic radiographs (Fig. 1): neck-shaft angle, abductor lever arm, position of head center relative to the tip of the greater trochanter. Intramedullary parameters were also calculated including width of the proximal and distal medullary canal in order to determine the femoral enlargement index according to Noble et al. [21]. We also measured the angle of gluteus medius activation that is the distance between the vertical line running through the extreme point of the anterior and superior iliac spine and the line running through that point and the most lateral point of the greater trochanter (Fig. 1).

Results

Among the studied population, lateralization was normally distributed (Gaussian distribution). Mean lateralization value was 39.7 mm (s.d. = 5.7) ranging from 25 to 60 mm. Features of other studied parameters were the following: Neck-shaft angle: 129° (s.d. = 6), H height of C center: 58.8 cm (s.d. = 8.6), abductor lever arm: 7.8 cm, proximal femoral width: 45.4 mm (s.d. = 5.7), distal femoral width: 13.5 mm (s.d. = 2.6), femoral enlargement: 3.45 (s.d. = 0.61), angle of gluteus medius activation: 6° (s.d. = 1).

Lateralization was independent from endomedullary features (width of proximal femoral canal, femoral enlargement). Height of the head center [22] relative to the lesser trochanter and lateralization were independent parameters. Abductor lever arm was poorly correlated to lateralization but significantly correlated to the gluteus medius activation angle ($p < 0.001$).

Discussion

Our findings corroborate those reported in the literature; however, anatomical studies appear to overestimate lateralization compared with radiographic studies, undoubtedly resulting from a better control of rotation. Since Leyvraz et al. findings, [1], it is widely accepted that horizontal-dimensional parameters are highly influenced by femoral rotation. Lateralization is not exception to the rule. For instance, external rotation underestimates the true lateralization value. For this reason, accurate preoperative radiographs should be taken with the lower limb in internal rotation thus placing the patella in the frontal plane. The femoral neck is thus perfectly visible which allows accurate measurement of lateralization to the nearest mm during arthroplasty preorerative templating. According to statistical data, lateralization is independent from endomedullary parameters. These last findings advocate the use for a non homothetical size progression of the femoral neck when femoral implant is industrially manufactured. A single height of femoral head center might be coupled with a great variability and dispersion of lateralization. It appears to be problematic when femoral anatomical parameters need to be restored such as lateralization for restoration of abductor lever arm but also height of the head center for equalization of lower limb length. The insertion depth of the stem might be adjusted to easily modify the position of the head center. However, it appears more difficult to solve the problem of variation in lateralization. Thirty per cent of the subjects have a greater lateralization than that obtained with standard implants, even those featuring a long-neck design. Therefore, various surgeons resort to standard and lateralized femoral stems in order to best restore this parameter.

Conclusions

A great variability in femoral lateralization has been observed within the population. No correlation was found between lateralization and anatomical features, which might explain the routine use of standard and lateralized prosthetic implants.

Relationship between ''offset'' and shape of the medullary canal: How endomedullary parameters might help anticipate the position of the hip center?

The use of a stem design perfectly adapted to the shape of the proximal medullary canal while accurately reproducing the femoral lateralization raises an issue due to the variations of canal shape which are more important than in the diaphyseal region. Adjustment of stem insertion depth is limited since it depends on proximal adjustments. A relationship should be established to help assess the position of the hip center relative to each metaphyseal shape due to the lack of basi-cervical modularity. Therefore, a morphometric study has been carried out to look out for possible correlations between endo- and extramedullary parameters.

Material and methods

Two-hundred AP pelvic radiographs featuring a unilateral implanted hip were calibrated on the prosthetic head. A projection of the healthy femur in the frontal plane was obtained by aligning the medial margins of the greater trochanter. The studied population was described elsewhere [23].

Measurements of the metaphyseal dimensions, lateralization and height of the femoral head center were performed. The metaphysis was defined using the metaphyseal index MI, which is the ratio of two widths at a 2 cm gap, the lower one (*E*) being situated at the most prominent point of the lesser trochanter.

Results

E width was significantly correlated with femoral lateralization ($r = 0.25$, $p < 0.001$) but not with the height of the head center. The MI was significantly correlated with the height of the head center ($r = 0.39$, $p < 0.001$) and with lateralization ($r = 0.15$, $p < 0.05$).

When considering a constant *E* width, MI was correlated with femoral lateralization ($r = 0.34$) and height of the head center ($r = -0.44$) vary significantly ($p < 0.001$). From *E* and MI, the position of the head center could be recalculated in 74% of cases with a 5 mm precision and in 96% of cases with a 10 mm precision. The hip center was high and medial for low indexes (truncal metaphyses), whereas it was lower and lateralized for higher indexes (flared metaphyses).

Discussion

With equal size, lateralized designs showed a lower head center. Adaptation of the metaphyseal shape to the lateralization would notably improve the implant rotational stability [24], in order to control the torsional stress applied on the implant and its cement cover [16].

If well-designed, the implant ensures a satisfactory restoration of the normal anatomy of the hip in more than 90% of cases with a 10 mm precision, when the acetabular cup is well-centered (with no rise of the hip center). Such accuracy appears to be adapted to conventional surgery. However, improvement in accuracy, especially antero-posterior, requires a greater number of configurations and the use of navigation, which justifies basi-cervical modularity.

Accuracy of femoral offset measurement via conventional radiography

Abductor lever arm restoration in total hip arthroplasty has led to the development of ''lateralized'' femoral stems thus allowing an increase in femoral offset, major requirement for abductor lever arm restoration. However, preoperative measurement of femoral offset is currently performed with conventional radiographs. But various reasons might interfere with the accuracy of these measurements radiographic enlargement and hip rotational positioning. The aim of that work was to assess the margin of error when measuring femoral offset with conventional radiography compared with CT scan.

Material and methods

The present retrospective study includes 50 patients who consecutively underwent a total hip arthroplasty (THA). Two different methods were used for postoperative femoral offset measurement: radiographic measurement with Imagika™ software, and CT-scan measurement with Hip-plan™ (Symbios) reconstruction software. This 3D measurement was thus independent from the lower limb rotation. Both measurements were then compared, the CT-scan measurement being considered as the ''gold-standard''.

Results

Mean radiographic offset was 42.6 mm [range, 26.9 to 53.9 mm] and 45.8 [range, 31 to 56 mm] with CT-scan. When compared with CT-scan, radiographic offset was always underestimated, for an average of 3.2 mm ($p < 0.0001$) displaying values ranging from 0.1 to 12.5 mm. In 28% of cases, undervaluation exceeded 5 mm.

Discussion

Various aspects might compromise conventional radiographic measurement of femoral offset. Radiographic enlargement, which is hard to control, depends on the patient's build. We have measured radiographic offset from a postoperative view since we could precisely know the magnification factor (diameter of the prosthetic head is known). The lower limb rotational positioning might also be responsible for offset undervaluation when femoral neck is not perfectly visible. The measurement error in this study averaged 3 mm and exceeded 5 mm in 28% of cases. Moreover, our measurement was performed on operated hips thus less painful and more mobile. However, a higher error might have been reported if measurement had been taken in patients with painful injured hip, and a fixed external rotation contracture of the hip. The incidence of undervaluation appears to be low, however: a 3 to 5 mm measurement error represents about 10% of the global femoral offset value which usually ranges from 25 to 55 mm. Lateralized stems options afford the opportunity to increase femoral offset of about +6 mm. The value of the initial 3 mm offset undervaluation thus already corresponds to half the increase in femoral offset offered by a lateralized stem.

Conclusion

The mean radiographic femoral offset measurement error is 3.2 mm (and exceeds 5 mm in 28% of cases). Sufficient degree of freedom should be maintained during preoperative templating to achieve appropriate restoration of the abductor lever arm.

3D preoperative templating

Two-dimensional preoperative templating provides accurate assessment of center of rotation, leg length and femoral offset but has limitations for planning lower limb rotation. However, a normal gait implies a femoral anteversion of about 15°, a patella at its zenith (for optimum quadriceps function) and a gait angle of about 18°. Moreover, upper femoral torsion (or helitorsion) might compromise the accuracy of a 2D femoral offset analysis, a small version would increase it while an excess of anteversion would decrease it. Conventional radiography demonstrates low levels of reliability in evaluating the axis of the lower limb rotation which on the other hand might be easily determined using three dimensional computed tomography templates [1] (Fig. 3). CT-based computer templating provides the surgeon with the ability to determine femoral helitorsion (axis of stem insertion) and femoral anteversion (femoral neck axis). Once the desired stem anteversion axis is known, it is thus easy to calculate the alpha angle (difference between stem helitorsion and anteversion axis). When taking into account the surgeon's request regarding potential femoral lateralization and leg-length equality, measurements of the ideal femoral offset might be accomplished in 3D. Femoral helitorsion might be highly variable in secondary osteoarthritis or similar to the mean value in primary osteoarthritis but demonstrating significant individual variations [25—27].

In a preoperative analysis which included 1280 custom-made arthroplasties (684 primary osteoarthritis, 162 osteonecrosis, 129 hip dysplasia, 66 congenital hip dislocations and 116 for other reasons), helitorsion varied from −29° to + 118° (Table 1).

A cemented stem which is undercalibrated in its cement mantle might be rotated in order to obtain the desired stem anteversion angle. On the other hand, insertion in the

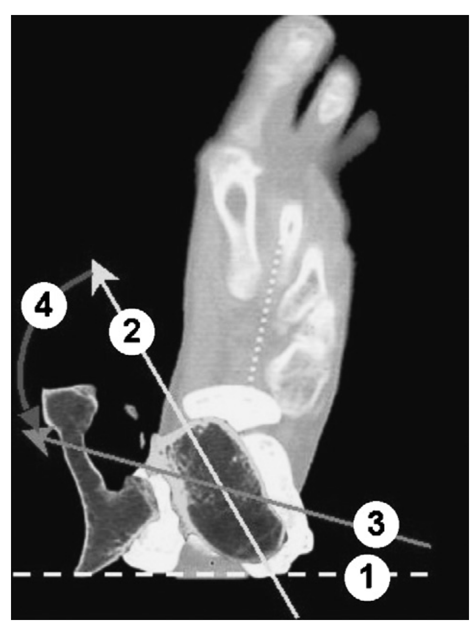

Figure 3 CT-scan measurement of various axes of the femur: 1: posterior bicondylar axis; 2: helitorsion axis; 3: prosthetic anteversion axis; 4: alpha angle.

Table 1 Mean and extreme values of femoral helitorsion and alpha angle measured with CT scan, according to aetiologies.

	Helitorsion	Alpha angle
Osteoarthritis	18.4° (−8°; +58°)	−3.4° (−43°; +23°)
ONA	16.8° (−11°; +45°)	−1.8° (−30°; +26°)
DDH	22.8° (−10°; +62°)	−7.8° (−47°; +25°)
CDH	38.4° (−5°; +118°)	−23.4° (−103°; +20°)
Miscellaneous	20.5° (−29°; +65°)	−5.5° (−50°; +44°)

ONA: osteonecrosis; DDH: developmental dysplasia of the hip; CDH: congenital dislocation of the hip.

helitorsion axis (may be excessive) of a cementless stem, moreover featuring a preferential metaphyseal fixation, might induce postoperative anterior instability or exaggerate lower limb internal rotation. A derotation osteotomy, modular neck or custom-made femoral stem might then be useful (Fig. 4). The use of straight femoral components designed for metaphyso-diaphyseal anchorage should be considered since this might be inserted in nearly any rotation without any additional device other than adapting the implant size to the long axis of the medullary canal in the chosen rotational orientation.

Conclusion

Any total hip arthroplasty should take into account the horizontal plane (helitorsion axis) for proper understanding of normal gait criteria and accurate 3D preoperative planning since it might modify offset analysis by ''trigonometric'' effect. Therefore, it requires computed tomography software analysis. If proper femoral offset failed to be restored with a standard stem, the use of a custom-made femoral stem could then be considered.

Restoration of femoral offset and clinical function (THA vs Resurfacing)

Femoral offset restoration is recognised as an important part of Total Hip Arthroplasty (THA) procedure [3,29,32]. After Surface Replacement Arthroplasty (SRA), femoral offset is reduced due to the femoral component valgus position [30]. The aim of that study was to compare the clinical function of SRA and THA patients according to the femoral offset restoration.

Material and methods

Two hundred and ten hips (194 patients aged 23 to 65 years) were randomly assigned to two treatment groups: the THA or SRA group. From that initial group, only 156 patients were retained (THA = 76, SRA = 80) with an operated hip and a healthy contralateral hip (no history of arthrosis or THA). In both groups, a metal-on-metal bearing surface was used and surgery was performed through a postero-lateral approach. Preoperative clinical data and etiologies were identical in both groups (gender, age, size...). Standardized pre- and postoperative radiographs were made via Imagika™ software [20] for measurement of femoral offset [2]. Clinical and functional Postel Merle d'Aubigné, Womac and SF-36 scores, limping and/or Trendelenburg sign were reported.

Results

Compared to the normal contralateral side, the femoral offset increased on average 4.85 mm (range, −2.8 to 11.6) in THA patients and decreased an average of 3.42 mm (range, −7.8 to 0.2) in SRA patients ($p < 0.001$). In the THA group, femoral offset was increased in 84% of cases whereas it was decreased in 80% within the SRA group (57% of SRA induced an offset reduction exceeding 10%). No significant

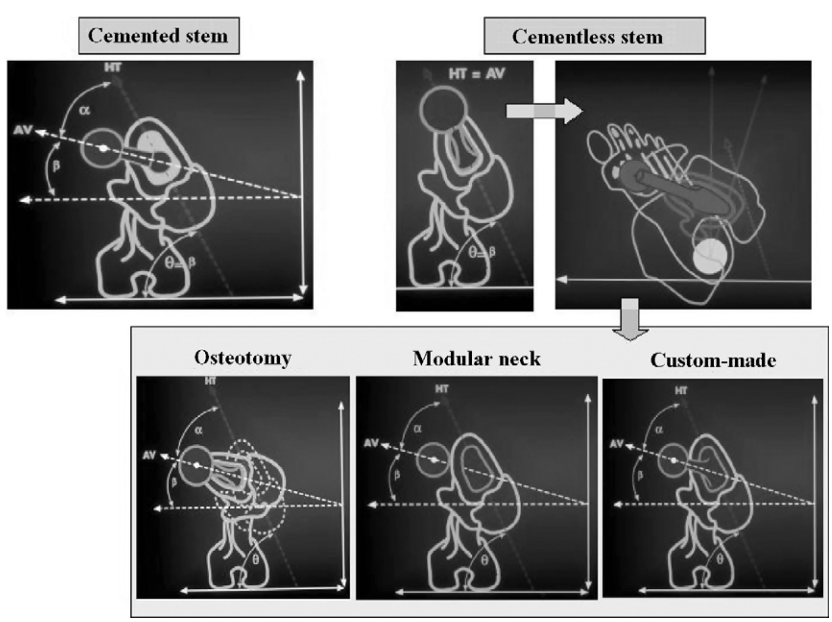

Figure 4 Stem positioning according to the type of prosthesis and fixation method.

Table 2 Mean values (standard deviation and extreme) of femoral parameters measured with the Imagika™ software prior to and after insertion of a double tapered stem.

Value in mm	Preoperative	Postoperative	Mean delta	Min/Max	Standard deviation
Femoral offset	34.9	36.9	+1.6	−21/+20	7.78
Global offset	69.2	68.9	−0.3	−21/+19	7.94
Abductor lever	43.8	45.3	+1.65	−6/+5	3.18
Difference in length	−4.2	+2.42	+6.3	−9/+16	6.42

differences were found between the two groups in terms of clinical scores. For the THA and SRA groups, the Postel Merle d'Aubigné scores were respectively 17.7 and 17 points, the SF-36 scores 101 and 100.7 points, the WOMAC scores 11.7 and 9.2, the rate of limping 11.1 and 10.3% ($p > 0.05$). No Trendenlenburg sign was observed in the THA group whereas a 3% rate was reported in the SRA group ($p > 0.05$).

Discussion

The decrease in femoral offset after SRA does not affect the clinical function and even appears advantageous for cervico-cephalic osseous support since it converts shearing stress into axial compressive forces. The comparable excellent clinical outcome reported in both series does suggest that femoral offset restoration is not as crucial for the success of SRA as for that of THA. The ''big head'' effect secondary to the prosthetic restoration of the initial femoral head diameter is probably responsible for this result through proprioception and improvement of joint stability [28,29].

Influence of femoral modular necks on offset restoration during Total Hip Arthroplasties

Theoretically, modular neck is a reliable solution to provide accurate femoral offset restoration since a single center of rotation can be coupled with a 8° valgus or varus neck thus allowing a variation in offset of 16 mm and even up to 20 mm when using a 15° varus neck (Fig. 5). Clinical validation is based on a study including the first 120 patients continuously operated on between 2001 and 2003 and treated with

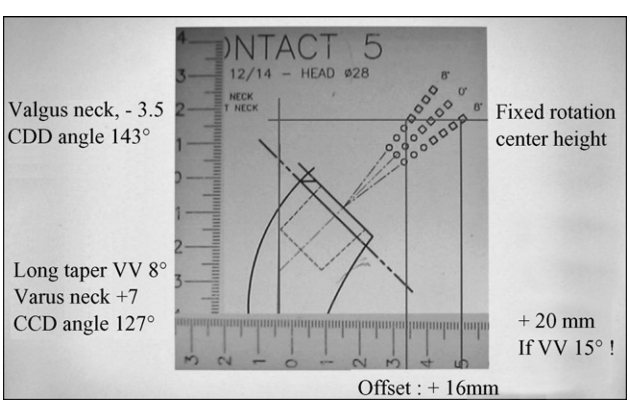

Figure 5 Effects of modular hip tapers. Modification of neck angle combined with that of its length allows to adapt the limb length and offset value.

a Contact-E™ stem coupled with a modular neck (Wright-Medical). Patients were reviewed at a minimum follow-up of four years by an independent examinator, radiographs were digitized on a Télé-Rad Pro™ scan then analyzed with Imagika™ software (Table 2). All complications were early postoperative ones and included a deep infection, a femoral fracture and two dislocations (1.7%). Clinical evolution was normal, mean Harris Hip score increased from 47 to 92 postoperatively. Variations in femoral offset (+1.6 mm), global offset (−0.3 mm) and abductor muscle lever arm (+1.65 mm) are detailed in Table 2. These measures are influenced by pre-operative osteoarthritis external rotation position. If excluding cases in which more than 5 mm difference was found between healthy contralateral femoral offset and preoperative offset, only 48 cases could be analysed with a mean variation of + 2.1 mm (−13, +14, standard deviation 4.2). Mean offset values are well-restored but demonstrate significant deviations even after excluding preoperative external rotation position. Femoral offset had decreased in 44 hips and increased in 76 which could be statistically correlated with the use of a long or short modular neck ($p = 0.001$). The latter being too short, its use should be avoided. Conversely, modular neck geometry did not have any significant statistical incidence although no decrease in offset was observed with varus femoral necks.

A low dislocation rate was reported (2/120 [1.6%]) due to the opportunity of intraoperative offset and neck anteversion adjustment (Fig. 5) thus reducing the risk of neck-on-cup impingement while providing proper soft tissue balancing. However, both cases of dislocation reported an increase in femoral offset of respectively +14 and +11 mm. In one case, dislocation was attributable to an excess in femoral anteversion corrected during early revision surgery with a retroverted femoral neck. Functional outcome was positively affected by femoral offset restoration since the 76 patient mean Harriis Hip score with increased offset was significantly higher ($p = 0.005$).

To conclude, the use of a modular neck facilitates prosthetic offset restoration and guarantees better results but requires great attention to avoid the drawbacks of a decrease or, on the contrary, an excessive increase as shown in this initial series.

A minimum six-year follow-up outcome after implantation of a high-offset femoral stem. A review of 94 cases

Increasing femoral offset will theoretically enhance hip stability [2,3,8,16], reproduce the anatomy of the natural femur [30], improve the abductor muscle strength [2] and also result in better femoral component fixation. However, this last notion is still under debate and the effect of a high increase in femoral offset on stability of a cemented femoral stem has not yet been fully evaluated [15,22]. The aim of that study was to investigate the behaviour of a Lubinus SP2 117° stem and compare its survival rate with that of a standard stem (126°), which reports the best survivorship among the range of all cemented stems previously investigated in the Swedish register [19].

Material and methods

A cohort of 94 hip prostheses, implanted between 1999 and 2001 at the Lille University Hospital, was reviewed by an observer who did not participate in surgery. A clinical and radiographic control was performed at last follow-up. Prostheses were implanted through the postero-lateral approach and cemented using a second-generation technique. Criteria for the choice of this implant were a neck-shaft angle under 135° (67% < 125°) and/or a high-offset design.

Results

The mean follow-up period was 78 months [70—94]. The Postel Merle d'Aubigné score at last follow-up was 17 ± 1.7 [13,18]. Among this population of patients with increased offset, the Lubinus SP2 117° could successfully reproduce the preoperative femoral offset in 91% of cases. Four dislocations occurred in patients with improper offset restoration with the femoral stem. In total, five revision surgeries were required: three for loosening of the femoral stem and two for instability. No pre- or postoperative femoral anatomical factor could be correlated with the occurrence of femoral loosening but two out of three loosenings resulted from an initial cementation defect (discontinuity) and a multi-operated femur (previous osteotomies) respectively. Survival rate of this implant was 95.1% (±4.8) after seven years (a 98% rate was reported in the Swedish hip arthroplasty register at 7-year follow-up for the non lateralized Lubinus stem [19]).

Discussion and conclusion

The increase in femoral component offset may result in a higher stress applied on the fixation interface [16]. Early loosening has been observed with high-offset cementless stems featuring a straight, cylindrical design [31]. The anatomical Lubinus SP2 stem design allows a uniform cement mantle which may potentially reduce the incidence of premature loosening. In our series, the survival rate at seven years is lower than that of 126° and 135° stems previously published in the Swedish report [19]. Besides, an increase in femoral offset was identified in the register as a contributing factor in surgical failure [19]. This implant thus appears as an appropriate solution in case of long femoral neck and/or neck-shaft angle less than 135° [22,32]. However, the slight decrease in the survival rate of this cemented implant requires the need for a longer-term follow-up.

Offset and navigation

Total Hip Surgetics™ V1.0 from Praxim-Médivision is a surgical navigation system which, among others, helps control offset/neck length restoration during total hip arthroplasty. We have been using it since February 2004 jointly with standard and lateralized Corail™ stems (DePuy). A review of the literature demonstrates that in only 60% of cases, surgical planning is performed intraoperatively while in 40% of cases, the objective is not achieved, in terms of length or offset control. We tried to analyse the causes and demonstrate to what extent the use of a navigational system might be an efficient tool for improving the accuracy of the surgical procedure.

Material and methods

We carried out a preoperative planning based on an AP radiograph of the pelvis in a cohort of 200 patients. The required length and offset delta was defined for each patient. All surgical procedures were performed with the navigation system. Divergences between initial objective and results were postoperatively controlled on a frontal radiograph of the pelvis. Outcome was considered as satisfactory when such difference was less than 5 mm.

Results

In 53% of cases, we had to intraoperatively modify the initial preoperative surgical plan to reach our objective. A rise ($mean_a = 4.5$ mm) and medialization ($mean_m = 3.5$ mm) of the acetabular center of rotation occured in 100% of patients. In 20% of cases, the femoral cut was situated more than 5 mm above the level of the preoperative plan. Length was restored in 98% of cases and when considering the offset-length couple, 78% of patients were less than 5 mm from the objective for both criteria. Antero-posterior displacement of the hip center of rotation was only measured on 16 occasions since this function was added later on when software was brought up to date. Mean antero-posterior displacement was 8 mm.

Discussion

Our results corroborate earlier findings reported in the literature. In 53% of operations, application of the preoperative planning would have been prevented from reaching the objectives. The reasons are: medialization and systematic rise of the acetabular center of rotation rarely aligned on the preoperative plan and height of cuts barely respected. However, the use of a navigational system allows proper restoration of limb length in all patients, by intraoperatively informing the surgeon of the changes to bring to reach the planned objectives. It also improves both offset and length which restoration is only limited by intraoperative selection of the available prostheses. Control of the antero-posterior dimension (the most modified parameter during surgical procedure) is not possible with a standard range of prostheses. Therefore, we believe the use of computer navigation associated with a modular neck hip prosthesis would be the best available combination to provide the widest range of solutions for proper control of complete spatial restoration of the femur. Such option would promote joint stability while enabling more accurate soft-tissue management.

Conclusions

Total hip replacement has been applied for more than 40 years. The goal was originally to provide relief of pain and approximate implant stability which was considered as a successful surgical outcome for both patient and surgeon. Nowadays, patients are more demanding since early and long-term restoration of a normal functional and physiological hip is one of their main expectations. Materials, bearing surfaces, fixation of implants being still under debate, the need for proper reconstruction of the hip morphologic features takes an ever-growing part in THA: ''a good hip architecture is necessary to achieve good function''. Total hip replacement requires the need to comply with very specific principles: the initial center of rotation of the hip must be restored or slightly medialized to ensure better acetabular component coverage while accurate femoral offset reconstruction will achieve effective lever arm of abductor muscles which plays an important part in gait cycle and implant longevity. Moreover, physiological anteversion and accurate limb length should be achieved. Precise preoperative planning is a mandatory but should take into account the inaccuracy of the radiographic scales. It reduces the risk for major errors but does not guarantee the result [33]. The operation requires the need for a precise and controlled surgical gesture. Navigation appears to enhance the accuracy of implant placement. The surgeon should have a broad selection of anatomical, lateralized, modular or custom made implants according to his requirements, in order to match each patient anatomy. Femoral offset restoration is recognised as an important part of THA procedure to improve joint stability and implant longevity.

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