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ORIGINAL ARTICLE

Navigation for total hip arthroplasty

O. Guyen[1], V. Pibarot[1], J. Bejui-Hugues[2], SCOR Group

[1] Service de chirurgie orthopédique et traumatologique, pavillon T, hôpital Édouard-Herriot, 5, place d'Arsonval, F-69437 Lyon cedex 03, France
[2] Istituto Chirurgico Ortopedico Traumatologico, via Franco-Faggiana, I-1668-04100 Latina, Italy

Abstract: Despite increasing advantages in biomaterials, prosthetic designs, and implant fixation, clinical outcome of total hip arthroplasty (THA) has 10% failure rate after 10 years. Component malposition is well known to be responsible for instability, impingement, excessive wear and early loosening. Computer-assisted procedures are expected to improve the accuracy of the components positioning and also the outcome of total hip replacements. We present the Amplivision© system (Amplitude, Porte-du-Grand-Lyon, Neyron, France) that has been used since October 2005 for total hip replacements at our institution. The surgical technique as well as the advantages of this system is described. The Amplivision© system allows accurate positioning of the acetabular and femoral components during THA and also the control of leg lengthening, offset and stability.

Keywords: Computer-assisted surgery – Total hip arthroplasty – Acetabular – Femoral component

Introduction

Total hip arthroplasty (THA) has become one of the most successful orthopaedic procedures to achieve relief of pain, restoration of function and quality of life. However, despite increasing advantages in biomaterials, prosthetic designs and implant fixation, clinical outcome of THA has 10% failure rate after 10 years [1-3].

Component malpositioning increases the risk of dislocation, reduces the range of motion (ROM) to impingement, and can be the cause for accelerating wear and early loosening. In addition, leg length discrepancy leads to discomfort, unhappiness and even litigation.

Improved implant alignment (with the use of navigation) is an important factor contributing to fewer complications following THA [4].

Optimal positioning of both cup and femoral components is essential for both reduction of the risk for dislocation and for the improvement of longevity [5].

To reduce the risk of complications, we developed the Amplivision© navigation system (Amplitude, Porte-du-Grand-Lyon, Neyron, France). This system enables the surgeon to control:

- the ROM to impingement and also the stability;
- the leg lengthening;
- the offset.

The goal of the present report is to describe the original concept and the surgical technique of the Amplivision© system.

Material and methods

Principle

The Amplivision© system has been developed to be compatible with:

- any position of the patient on the operating table (supine or lateral decubitus positions);
- any surgical approach;
- MIS or conventional procedures;
- any surgical sequence (the surgeon may choose to start with the acetabular component or the femoral component placement first);
- any type of total hip implants from Amplitude company (metal on polyethylene or ceramic on ceramic components, dual mobility implants, modular components);
- any reference plane (pelvic anterior plane or functional femoral reference plane).

Most of the existing navigation systems use the anterior pelvic plane (also called Lewinnek plane [3]) as the reference plane to guide the imageless computer-assisted surgery.

However, the reliability of this reference remains controversial [6].

Moreover, this plane cannot be used during surgery with the patient in lateral position. The Amplivision© system is an original concept that leaves the surgeon the choice to use or not such a plane. Because of the

Correspondence: jacques.bejui@chu-lyon.fr

limitation of this reference plane, the Amplivision© system allows the choice between the Lewinnek plane and a functional plane called "femoral reference plane".

This femoral reference plane is perpendicular to the sagittal lower limb plane defined by the center of the hip, the center of the knee and the center of the ankle with the knee flexed at 90° (Fig. 1).

Amplivision© system

The Amplivision© hardware system is a mobile device developed for both hip and knee computer-assisted replacements. It consists of optoelectronic Polaris stereo cameras that detect the infrared signals of the so-called "rigid bodies" (Fig. 2). Information is displayed and shown to the surgeon step by step on the monitor, as surgery is going on. A pointer allows the surgeon to select options (Fig. 3). A computer program calculates the center of the hip from the data obtained by surface matching. A sophisticated algorithm calculated direction and depth of the acetabular reaming and progression of the femoral rasp as well as the final components positions. In addition, the ROM to impingement as a function of the components positions (and therefore the stability) is displayed.

Easily understood graphical and numerical elements as well as virtual instruments displayed on the screen help the surgeon during the entire procedure. In case of technical malfunction, manual surgical procedure is always possible.

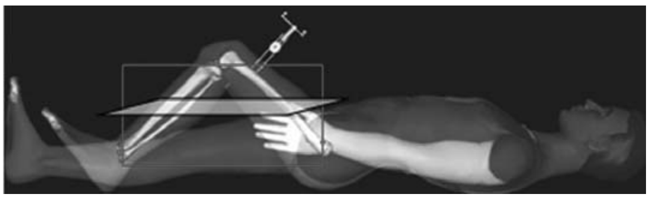

Fig. 1. The functional femoral reference plane (perpendicular to the sagittal lower limb plane) is shown

Fig. 2. The Amplivision© navigation platform is shown

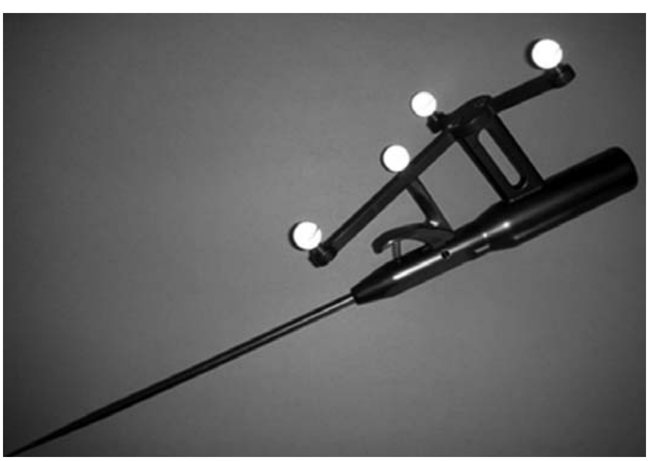

Fig. 3. The navigation pointer is shown

Surgical technique

We describe a primary computer-assisted right total hip replacement in a patient in lateral decubitus position using the transgluteal anterolateral Hardinge approach. We usually use the functional femoral plane as the reference plane. We usually perform the femoral component placement first.

The infrared cameras of the navigation platform should be placed about 2 m from the rigid bodies on the opposite side of the surgeon.

The first step consists of the following options (Fig. 4):

– type of acetabular and femoral implants;

– reference plane: Lewinnek pelvic anterior plane or functional femoral reference plane as described above;

– standard or MIS procedure (specific tools);

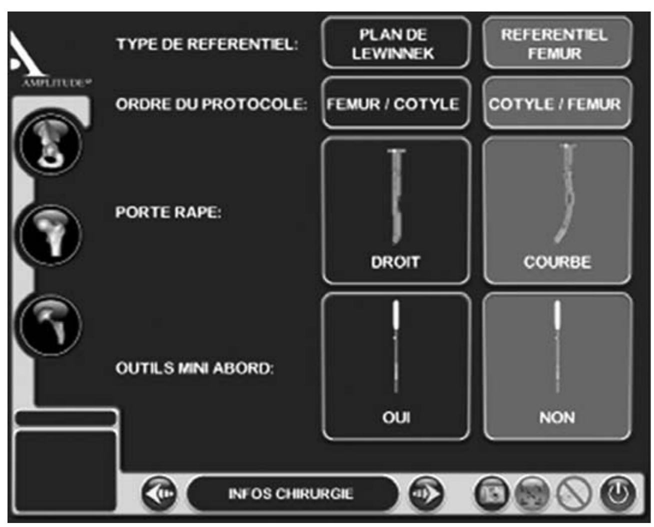

Fig. 4. The different options available at the beginning of the procedure are displayed

– and finally the choice to start with the acetabular or the femoral component placement.

Then the fixation of the rigid bodies (one on the iliac anterior crest, and one on the femoral shaft) is performed, using two pins for each rigid body to secure the fixation (Fig. 5).

A standard lateral transgluteal approach is used. Before the joint is dislocated, the leg is positioned in relation to the pelvis to simulate the standing position of the patient. The goals are to build the pelvis reference and to transfer the center of the femoral head into the pelvis. Then the hip is dislocated and the bone morphing of the femoral head is performed using the pointer to determine not only the center of the pathologic femoral head but also the native femoral anteversion and length (Fig. 6).

The acquisition of the medial and lateral epicondyles allows determining the center of the knee. The acquisition of the center of the ankle is performed with the knee flexed at 90° (Fig. 7). The femoral reference plane is perpendicular to the sagittal lower limb plane defined by these three points, as shown in Fig. 1. A position of the lower limb in a neutral position (foot on the ground) enables the transfer of its reference system to the pelvic system (creation of the pelvic reference system). The standing position of the lower limb is obtained by positioning the limb with the femur in line with the body and parallel to the ground and with the knee flexed at 90° to control rotation.

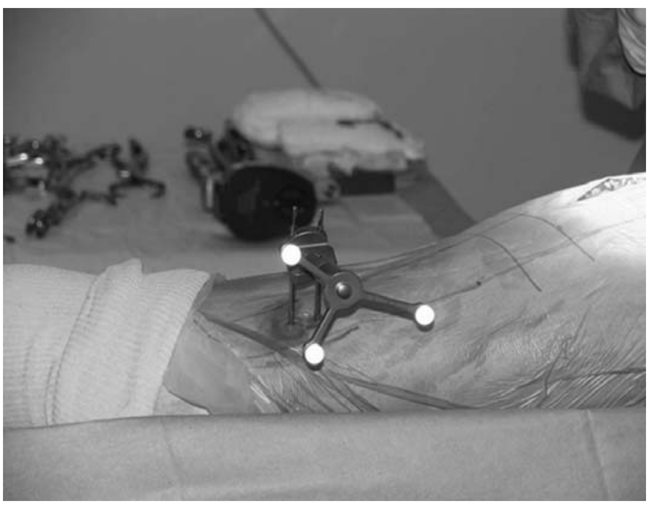

Fig. 5. A rigid body is placed on the femoral shaft

Femoral component placement

The next step consists of the femoral neck osteotomy, at a level determined by preoperative templating. A small conical reamer is then inserted into the medullary canal to determine the medullary axis. The rasps are then inserted until correct size is obtained. During this process, the femoral antetorsion of the rasp, the lateralization of the femoral center of rotation, the *varus/valgus* angle of the rasp with respect to the axis of the femur, and the height of the center of the prosthetic head (and therefore the change in the length of the leg) are continuously calculated and displayed as graphical and numerical information (Fig. 8). At this step, the rasp is maintained into the medullary canal.

Acetabular component placement

The next step consists of the acquisition of the bony landmarks of the acetabulum (i.e. anterior and posterior acetabular margins, true medial wall, and the top of the obturator foramen). Then the acetabular reamer position is critical to achieve stability according to the position of the femoral component. The Amplivision© system allows to orientate the acetabular reamer and also the

Fig. 6. The bone morphing of the femoral head allows calculating its center

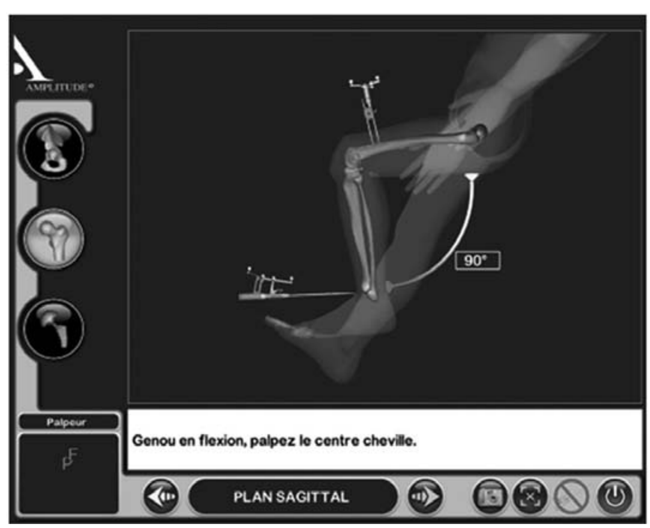

Fig. 7. The centers of the hip, knee and ankle are determined in order to define the sagittal plane of the lower limb

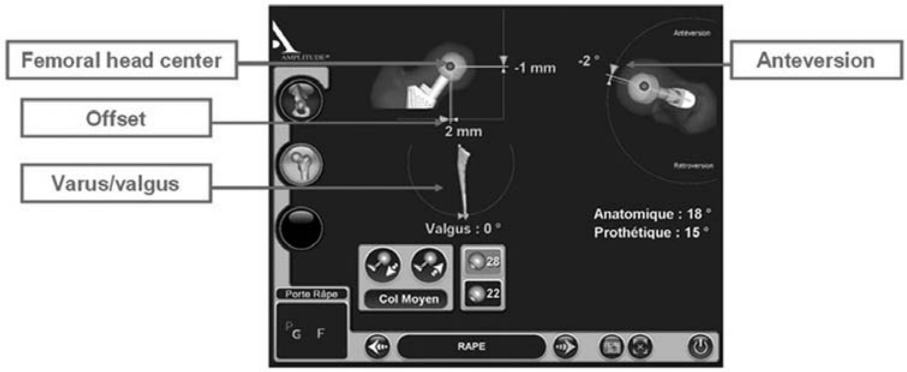

Fig. 8. During the insertion of the rasp, the femoral antetorsion, the lateralization of the femoral center of rotation, the *varus/valgus* angle, and the height of the center of the prosthetic femoral head are displayed

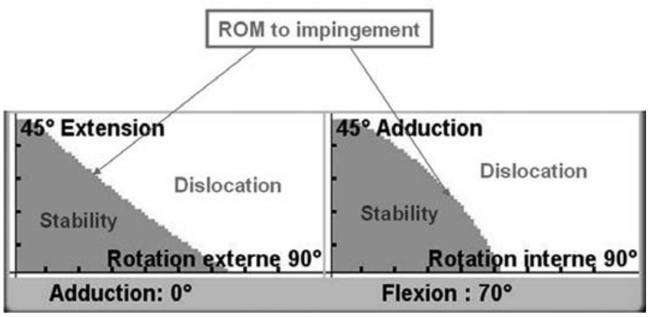

Fig. 9. The graph shows the surfaces of stability before impingement according to the orientation of the implants

acetabular component with respect to the femoral component according to the ROM to bony and prosthetic impingement. The ROM to impingement is displayed with graphs easily understood by the surgeon. The optimal placement of the components is achieved when the greatest surfaces before impingement are obtained (Fig. 9).

Once the correct positioning of the acetabular reamer is determined, subsequent reaming is performed under the control of the navigation system in 2-mm increments in order to accommodate a satisfactory press-fit. During this process, the progression of the reamer is continuously displayed on the screen and allows the control of the height and the depth of the center of the acetabular component in addition to the stability (Fig. 10). In case of acetabular reconstruction with bone grafting or osteosynthesis (dysplasia, post-traumatic arthritis, etc.) such a procedure is still possible.

At the discretion of the surgeon, a cup trial can be used at this time. The final acetabular component is inserted under the control of the Amplivision© system (Fig. 11).

Once the final acetabular component is inserted in proper position, the surgeon uses a prosthetic head trial (22, 28, 32 mm head with standard neck [short, medium or long] or with modular neck) on the previously inserted femoral rasp in order to assess full ROM and stability. At this time of the procedure, the surgeon is able to assess the leg lengthening with respect to the preoperative status, and to perform kinematic ROM test to assess the stability in any combination of flexion-adduction-internal rotation, and extension-external rotation (Fig. 12). In case of impingement, a warning (visual and acoustic) is displayed (Fig. 13).

Once the stability, neck length and femoral offset are achieved, the rasp is extracted. The surgeon inserts the final femoral component and the selected prosthetic head under the control of the Amplivision© system (Fig. 14).

Then the result of the final acetabular and femoral components is available: global leg lengthening, global offset and ROM to impingement are displayed (Fig. 15).

The surgeon is able to perform the same kinematic ROM test to assess the stability with the final implants. The closure is comparable with a conventional procedure.

At the end of the procedure, the data from the navigation system are saved and exported to the clinical follow-up software.

Clinical application

We have been using this Amplivision© system for 3 years at our academic institution and also in six private hospitals. Currently, a total of 528 computer-assisted primary total hip replacements have been performed at our institution. Encouraging early results have been presented at the "Journées de navigation Paris-Lyon-Marseille" in 2005 and 2008. Early to mid-term outcomes of this series are currently under evaluation. Compared with conventional procedures, no additional morbidities have been observed.

Conclusion

The Amplivision© system allows accurate positioning of the acetabular and femoral components during THA and enables the surgeon to control leg lengthening, offset and stability. Therefore, an improvement of the outcome of

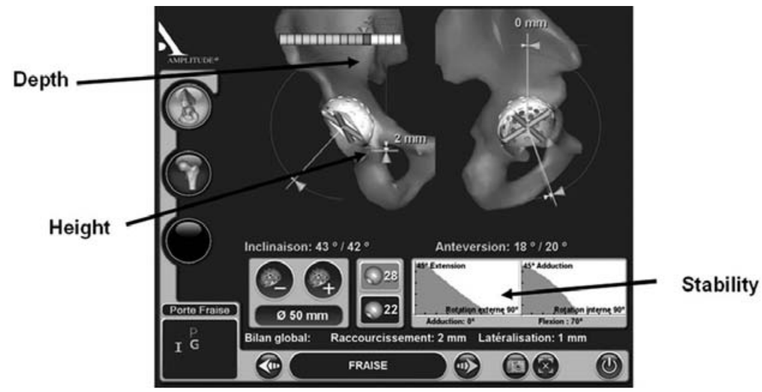

Fig. 10. During the acetabular reaming, information regarding the depth and the height of the reaming as well as ROM to impingement is displayed

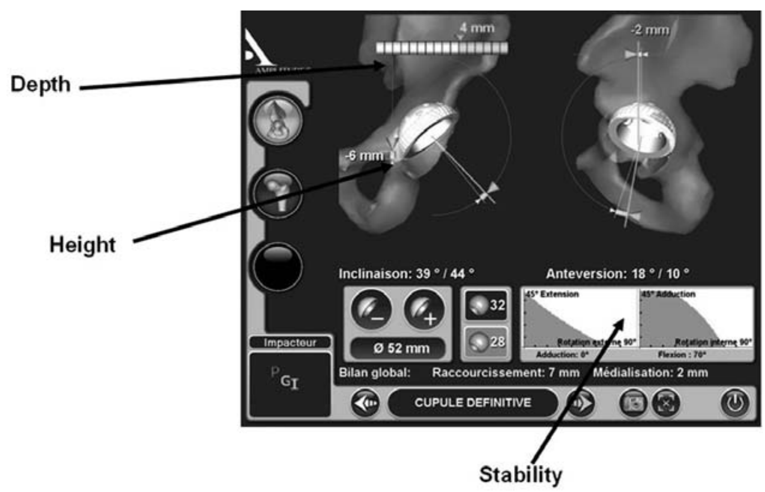

Fig. 11. Information regarding the depth, the height, and the ROM to impingement is also available for the final acetabular component

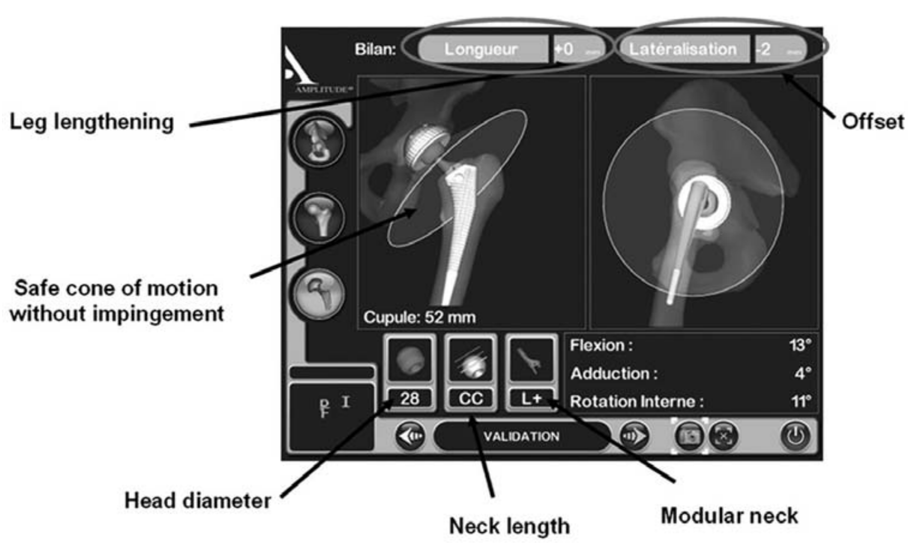

Fig. 12. A kinematic ROM test to assess the stability is performed (note the information regarding the leg lengthening and offset)

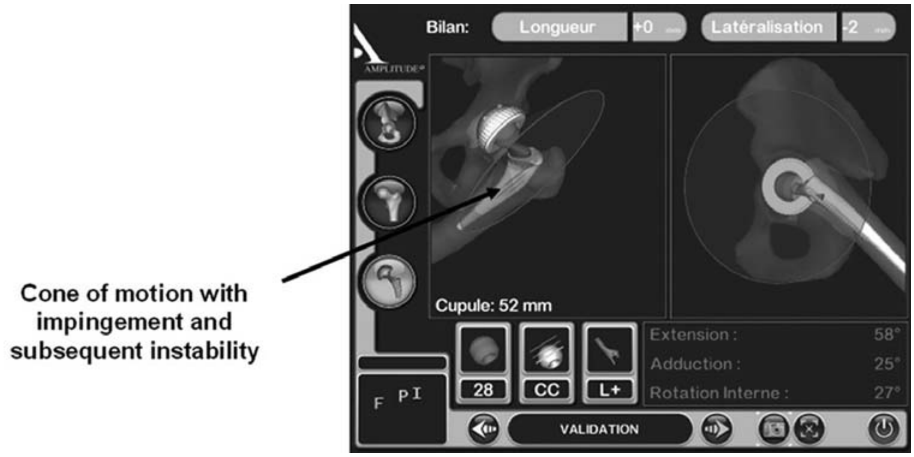

Fig. 13. In this case, the kinematic test shows evidence of impingement and instability

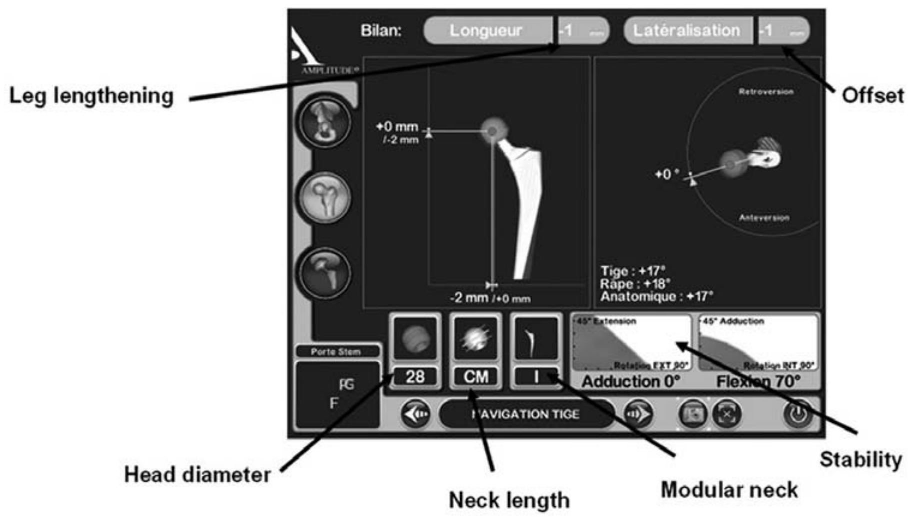

Fig. 14. The assessment of the final femoral component positioning is shown

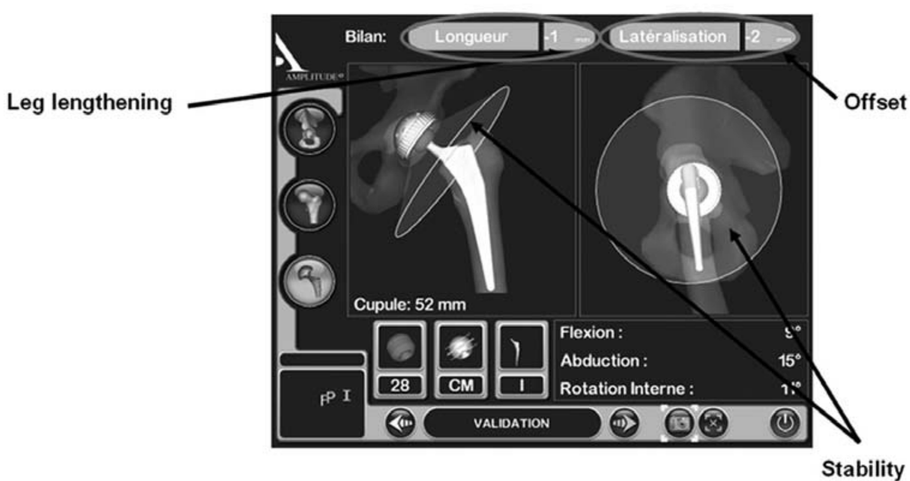

Fig. 15. The final assessment of the procedure is shown

the arthroplasty can be expected. Longer clinical follow-up is required to confirm this assumption.

Compared with other commercially available navigation systems, Amplivision© system offers the surgeon a large choice of options:

- cementless or cemented implants;
- any bearing surfaces including dual mobility implants;
- the use of conventional or modular implants;
- Lewinnek or functional femoral reference plane;
- surgery in supine or lateral decubitus position;
- any surgical approach including standard or MIS.

In addition, in case of technical malfunction, manual surgical procedure is always possible.

In our experience, we have been using this system since November 2002 for total knee replacements, and since October 2005 for primary total hip replacements, including challenging situations of abnormal hip morphology (dysplasia, femoral and acetabular osteotomies, etc.).

As for any other computer-assisted system, a learning curve is necessary. However, the Amplivision© system remains user-friendly.

Currently, we extend the application of computer-assisted surgery to revision total hip procedures.

References

1. Dorr LD, Wan Z (1998) Causes of and treatment protocol for instability of total hip replacement. Clin Orthop Relat Res 355: 144-51
2. Hassan DM, Johnston GH, Dust WN, et al. (1998) Accuracy of intraoperative assessment of acetabular prosthesis placement. J Arthroplasty 13: 80-4
3. Lewinnek GE, Lewis JL, Tarr R, et al. (1978) Dislocations after total hip-replacement arthroplasties. J Bone Joint Surg 60(2): 217-20
4. DiGioia AM, Jaramaz B, Blackwell M, et al. (1998) The Otto Aufranc Award. Image guided navigation system to measure intraoperatively acetabular implant alignment. Clin Orthop Relat Res 355: 8-22
5. Berry DJ (1999) Dislocation. In: Steinberg ME, Garino JP (eds) Revision total hip arthroplasty. Lippincott, Williams and Wilkins, Philadelphia, pp. 463-81
6. Pinoit Y, May O, Girard J, et al. (2007) Low accuracy of the anterior pelvic plane to guide the position of the cup with imageless computer assistance: variation of position in 106 patients. Rev Chir Orthop Reparatrice Appar Mot 93(5): 455-60