SUMMARY
Three methods for locating operated and non-operated hip joint centers (HJC) were compared in patients undergoing hip arthroplasty. X-ray measurements were used to determine the true HJC location and compared to HJC calculated using predictive versus functional approaches. The distance between the HJC and the mid pelvis (distance $HJC-MID\, PELVIS$) was calculated in the frontal plane. A 2-way ANOVA highlights that the functional method is more accurate than the predictive method in special conditions such as patients undergoing hip arthroplasty but no effect on the operated versus non-operated HJC was found. The functional method should be used in gait analysis in order to get better precision on angular joint position and moment calculation.

INTRODUCTION
Actual location of the lower limb joint centers is simple for ankle and knee joints while the estimation of the HJC is more difficult because the joint center is located underneath the skin surface and bony landmarks. HJC mislocation will affect joint kinematics and kinetics and can lead to misinterpretation about the joint dynamics especially when comparing pre-operative/post-operative conditions, operated/non-operated legs or control/patients.

In order to estimate the three-dimensional (3D) HJC location, predictive methods based on linear regression of various pelvis dimensions have been developed. They often use distances between reflective markers placed on bony landmarks. Contrariwise, this method should not be applied to patients with pelvis deformation because it assumes a perfect symmetry between both hips [1].

To improve the HJC location, functional methods have been developed. They use the geometry of the thigh movement relative to the pelvis according to its three degrees of freedom in rotation (flexion/extension, abduction/adduction and circumduction) [2]. This method is probably more accurate for pathological subjects, like in hip arthroplasty patients, because it accounts for individual hip geometry.

After hip arthroplasty, an accurate HJC location is required to estimate moments acting at the hip. The purpose of this study is twofold 1) to compare two approaches, predictive and functional methods, to determine the 3D location of the HJC in patients with hip arthroplasty and compare them with X-ray measurements 2) to determine if there is an effect on the operated side compared to the non-operated leg.

METHODS
All patients were diagnosed with hip osteoarthritis and had a surgical intervention using a posterior approach.

All subjects were asked to maintain their trunk in an upright position and to perform three repetitions of the star arc movement for both legs as described in [3] in order to locate the HJC. The star arc movement consists in five movements from hip flexion to extension in the frontal plane with two abductions in-between plus a circumduction. These movements were performed without pain at subject’s selected velocity, range of motion. Kinematics was recorded (60 Hz) from an 8 Vicon cameras systems.

From the 3D HJC locations of the predictive and functional methods, distances between the HJCS and the mid pelvis (distance $HJC-MID\, PELVIS$) were calculated in the frontal plane and compared to the X-ray measurements (Fig. 1).

Figure 1: The distance between the HJC and the mid pelvis (distance $HJC-MID\, PELVIS$)

Statistical analyses were performed using SPSS 17.0. The results were analysed using a 2-way ANOVA for the methods (predictive, functional, X-ray) and the leg (operated, non-operated). The results were then further analysed with Tukey post-hoc test. All analyses were done with a level of signification set at 0.05.

RESULTS AND DISCUSSION
A statistical significance was found between the distances $HJC-MID\, PELVIS$ from predictive method compared to the X-ray measurements while no statistical difference was found for the functional method (Fig. 2). These results suggest that the
location of the HJC from predictive method is not accurate in comparison to the X-ray measurement.

No statistical significance was found for the (distance $HJC_{MID\ PELVIS}$) between the operated versus non-operated. These results suggest that there is no difference in the HJC locations between the two legs. Restoration of biomechanics of the operated leg was performed base on pre-operative template using the opposite side as a reference and by using intra-operative bony landmarks.

The absence of a statistical significance between the functional method and the X-ray measurements according to the distance $HJC_{MID\ PELVIS}$ in the frontal plane suggests that this method is more accurate than the predictive method to determine the location of the HJC in pathologic patients. In other words, during more challenging conditions, where the hip’s geometry is modified and the range of motion is reduced, the functional method is still more efficient to determine the exact location of the HJC.

The absence of a statistical significance between the two legs demonstrates that even if hip geometry is altered only on one side (the operated leg), HJC’s locations are similar for both legs since the position is either modified laterally or medially.

Our results corroborate those from Piazza et al., [4]. They highlighted that it was possible to determine HJC location with an acceptable small error in pathological subjects. This method is feasible and it would have an impact on the calculation accuracy in hip joint angles and moments. Results from these analysis might also help during the surgical intervention and the rehabilitation processes.

In order to improve the HJC location, several markers could be used to provide redundant information in pelvis and thigh kinematics and consequently reduce soft tissue artifact. The comparison between methods and X-ray would be more accurate if anterior superior iliac spine were always visible. It would be easier to compare them in the same reference frame and to study the relation between the landmarks. Furthermore, because X-ray are always taken pre and post surgery, they could be used to improve the HJC location. This would ensure a high accuracy on the moments of force acting at the hip, especially on the abductor moment.

CONCLUSION
Patients undergoing hip arthroplasty are a challenging population for the determination of the HJC because their hip geometry has been modified and they have a reduced range of motion. In such conditions, the functional method is more accurate for the HJC frontal location than the predictive method when compared to X-ray measurements.

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REFERENCES