Computer-assisted intraoperative measurement of leg-length in total hip arthroplasty

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Introduction: Correct postoperative leg length restoration is among the most important goals of hip arthroplasty. Leg length inequality could be associated with hip and back pain, gait disorders, prosthetic impingement with the risk of dislocation, increased polyethylene wear, and could result in early revision surgery [2,4,5]. Most importantly, significant leg length inequality can lead to patient dissatisfaction.

Several techniques are commonly used to measure leg length intraoperatively. Most of these techniques are based on identification and comparison of fixed points on the pelvis and the femur before hip dislocation and after implantation of the prosthesis using mechanical jigs or tape measuring. Other methods include comparing the dimensions of the resected bone with the dimensions replaced by the prosthesis or visual comparison of points on non-calibrated pre- and intra-/postoperative radiographs. These techniques have not been reliable because they depend on accurate and reproducible femur repositioning [2,5]. For example, a femur malpositioning in 10° adduction and 10° extension would lead to an apparent error of 13.8mm in leg length [5]. To address the problem of reproducible femur repositioning, several computer-assisted methods were introduced [5,6]. However, these methods showed remarkable disadvantages. They have the need to calculate the hip joint center, which is difficult or often impossible in these mostly destroyed joints and they have the need to establish a femoral coordinate system which is time-consuming.

Therefore, we developed, validated and clinically applied a novel software algorithm based on surgical navigation, which allows the surgeon to restore a defined femur position without establishing a femoral coordinate system or the hip joint center and measure the leg length accurately and simply [1,3].

Material and Methods: This new leg length algorithm was used in 154 hips (145 patients) that underwent CT-based computer-assisted THA with a tissue preserving superior capsulotomy. There were 85 right and 69 left hips, the male-to-female ratio was 85:69 and the mean age at operation was 57 ± 12.8 years (range, 19 – 85 years). Intraoperatively, a pelvic and a femoral dynamic reference bases (DRB) were applied and the anterior pelvic plane (APP) was set as the pelvic coordinate system. Then, the hip joint was put in a neutral position and this position, and the relative position of the femoral DRB relative to the pelvic DRB, was captured and stored by the navigation system. After implantation of the prosthesis the same above described femoral position with the same amplitude of flexion/extension, abduction/adduction and rotation was restored. Now, any resulting difference was due to linear changes (Figure, left).

Validation of this new algorithm was performed by comparing the navigated results to measurements from calibrated antero-posterior pre- and postoperative radiographs. To adjust the postoperative X-ray for magnification the known cup diameter was used. To calibrate the preoperative X-ray, the interteardrop distance of the preoperative radiograph was compared to the one on the calibrated postoperative X-ray. To minimize the influence of pelvic tilt on leg length measurement, the difference in leg length between the operated and the non-operated side were computed (Figure, right). To calculate the radiographic leg length change the preoperative difference was compared to the postoperative difference. The radiographic results were compared to the mean leg length change measured with the navigation system (average of 3 single leg length measurements).
Left: The femur is tracked in the pelvic coordinate system which allows for exact repositioning and accurate leg length change measurement. Right: The validation of this algorithm was done on calibrated antero-posterior pelvic radiographs; the change in leg length between the pre- and postoperative status were compared to the results of the navigation system.

Results: No significant difference was found between radiographic leg length change and the results from the navigation system (p=0.658). The mean preoperative leg length difference was -4.7 ± 5.8 mm (range, -30 -11 mm), the postoperative difference was 1.3 ± 4.9 mm (range, -20 – 15 mm) and the resulting mean radiographic leg length change was 6.0 ± 4.4 mm (range, -5 – 20 mm). The mean leg length change measured with the navigation system was 6.5 ± 4.3 mm (range, -2 – 22 mm). The mean difference between the radiographic results and the results from the navigation system was -0.5 ± 1.8 mm (range, -5 – 4 mm). The mean registration accuracy of the navigation system was 2.04 ± 0.58 mm (range, 0.70 – 3.00 mm).

Discussion: This novel tool has the potential to increase the accuracy and consistency of leg-length change measurement during hip arthroplasty. Improved methods of measuring leg length change during surgery are even more critical now, when smaller incisions are being used, because traditional mechanical measurement methods are potentially even more unreliable than they are when larger exposures are used. This current method of measuring leg length change eliminates the need to calculate the center of rotation of the arthritic hip joint, which is often not accurately possible, and eliminates the need to establish a femoral coordinate system, which can be time consuming and frustrating. Besides registration accuracy, validation with plain radiographs is another potential source of error. Nonetheless, there was a substantial agreement between the radiographic results and the results from the navigation system. This novel computer-assisted method represents an accurate and simple tool for intraoperative leg length measurement.

References