Compensation for Pelvic Tilt by Adjusting Cup Angles using Computer Navigation during Total Hip Arthroplasty
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Introduction: CT-based computer navigation facilitates acetabular component placement in total hip arthroplasty (THA). However, in some patients, cup angles differ greatly between navigation and postoperative standing X-rays. It has been reported that pelvic orientation (flexion extension) influences radiographic acetabular alignment after THA. Cup angles on standing depend on pelvic flexion extension and should therefore be modified during THA for patients with severe pelvic flexion extension to obtain ideal postoperative standing cup angles.

The purposes of our study were firstly to evaluate the accuracy of CT-based computer navigation for acetabular component placement in THA, and secondly to examine the influence of pelvic flexion extension on standing cup angles.

Materials and Methods: CT-based computer navigation (Medtronic Navigation Inc., Louisville, USA) was used with 100 patients. The pelvic angle (PA), pelvic morphologic angle (PR-S1), sacral slope (SS) (Jackson et al.), and radiographic anterior pelvic plane (RAPP) (DiGioia et al.) were measured as parameters of pelvic orientation on preoperative standing lateral radiographs of the pelvis (Figure 1). Cup inclination and anteverision angles of navigation were compared to postoperative computed tomography (CT) images and standing X-rays. In measurement of cup angles on postoperative CTs, we input CT data into the computer navigation system, and segmented the cup using navigation software. After segmentation of the cup, we overlaid the segmented cup completely with the same-size trial cup on the computer, and measured the cup angles relative to the anterior pelvic plane (Figure 2). Cup angles of navigation and postoperative CTs were converted to radiographic angles. Cup angles on postoperative X-rays were measured in the way used by Lewinnek. Discrepancies in cup angles between postoperative CTs and standing X-rays were calculated to clarify the necessary adjustment, and the correlation between these discrepancies and preoperative pelvic orientation (PA, PR-S1, SS, and RAPP) was evaluated.

Results: In navigation, CT, and standing X-ray, cup inclination was a mean 41.8 ± 2.9, 41.7 ± 5.4, and 44.9 ± 5.2 degrees respectively, whereas cup anteverision was 19.5 ± 6.8, 19.5 ± 7.9, and 20.8 ± 6.3 degrees. There was no difference in cup angles among navigation, CT, and standing X-ray statistically; however, there was a wide range of discrepancies in cup anteverision between CTs and standing X-rays (range, 0 to 28.4 degrees). The discrepancy in cup anteverision between CTs and standing X-rays correlated with preoperative PA (r=0.48, p=0.0002), SS (r=0.45, p=0.0005), and RAPP (r=0.65, p<0.0001). From the regression line, a modification of 6 degrees in anteverision was needed for every 10 degrees of RAPP (Figure 3). The discrepancy in cup inclination between CT and standing X-ray did not correlate with PA, PR-S1, SS, or RAPP.

Discussion: Computer angles were the same as postoperative CT angles, which meant that precise placement of the acetabular component on the pelvic reference plane (anterior pelvic plane) was achieved. Therefore, computer navigation will be helpful for intra-operative adequate modification of the acetabular component in patients with severe pelvic flexion extension with regard to preoperative measurements of pelvic orientation. From our correlated results, preoperative RAPP was the best parameter for modification of cup anteverision, and the anteverision angle of the acetabular component should be modified by 6 degrees for every 10 degrees of preoperative RAPP.

Figure 1 Radiographic parameters of pelvic orientation A: posterior superior corner of S1, B: pubic tubercles, C: anterior superior iliac spines, a: pelvic angle, b: pelvic morphologic angle, c: sacral slope, d: radiographic anterior pelvic plane.

Figure 2 Measurement of postoperative CT cup angles A segmented cup is overlaid with the same-size trial cup, and cup angles (circles) are measured using navigation software.

The discrepancy in cup anteverision between CT and standing X-ray correlates with preoperative radiographic anterior pelvic plane (RAPP) (r=0.65, p<0.0001). From the regression line, the discrepancy increases by 6 degrees for every 10 degrees of RAPP.