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The accuracy of free-hand cup positioning - a CT based measurement of cup placement in 105 total hip arthroplasties

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Abstract We studied 105 patients who received a total hip arthroplasty between June 1985 and August 2001 using freehand positioning of the acetabular cup. Using pelvic CT scan and the hip-plan module of SurgiGATE-System (Medivision, Oberdorf, Switzerland), we measured the angles of inclination and anteversion of the cup. Mean inclination angle was 45.8°±10.1° (range: 23.0–71.5°) and mean anteversion angle was 27.3°±15.0° (range: −23.5° to 59.0°). We compared the results to the "safe" position as defined by Lewinnek et al. and found that only 27/105 cups were implanted within the limits of the safe position. We conclude that a safe position as defined by Lewinnek et al. [13] was only achieved in a minority of the cups that were implanted freehand.

Résumé Nous avons étudié 105 malades qui ont eu une Arthroplastie Totale de la Hanche entre juin 1985 et août 2001 avec positionnement manuel de la cupule acétabulaire. Utilisant une tomodensitométrie pelvienne et le module de hanche de SurgiGATE© - System (Medivision, Oberdorf, Suisse) nous avons mesuré les angles d'inclination et d'antéversion de la cupule. L'angle moyen d'inclination était 45.8°±10.1° (gamme: 23.0° à 71.5°) et

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l'angle moyen d'antéversion était 27.3°±15.0° (gamme: -23.5° à 59.0°). Nous avons comparé les résultats à l'orientation de sécurité définie par Lewinnek et al. et nous avons trouvé que seulement 27/105 cupules ont été implantées dans les limites de l'orientation correctes. Nous concluons qu'une orientation de sécurité, comme défini par Lewinnek et al. [13] n'a été obtenue que dans une minorité des cupules implantées manuellement.

Introduction

In total hip arthroplasty (THA). optimal placement of both cup and stem is essential for a satisfactory result [13, 14]. Malpositioning of one or both components significantly increases the risk of failure [2, 9, 10] and various complications like high rate of wear, early loosening or postoperative dislocation of the prosthesis may occur. The reported incidence of early dislocation after primary THA ranges from 1 to 10% [2, 9, 10, 13, 14, 16, 21]. Malpositioning of the components may be caused by misjudgment of the pelvic position during implantation [20].

The exact degree of anteversion of the acetabular cup cannot be determined from conventional radiographs unless they are acquired under defined conditions [20]. Tannast et al. [20] demonstrated that the cup position can be severely miscalculated without a standardized reference system. Using CT-based calculation, an exact reference plane can be defined. Such reference provides highly accurate information of the three-dimensional cup position [15, 19, 20]. In the current study, orientation of the acetabular components was determined using a CT scan of the pelvis.

Material and methods

Of all patients who received a primary THA between June 1985 and August 2001, 105 were selected to receive a computer-assisted THA in the contralateral hip at a later date. The first THA was implanted with freehand conventional technique using no surgical guides, whereas computer-assisted surgery was planned for the opposite hip implantation. Patients were specifically asked about hip instability or any dislocations in the past. Patients with instability or dislocation were excluded from the study.

At surgery, the mean patient age 62.3 (42.8–81.8) years; 60 female and 45 male patients were included. Fifty-four prostheses

Fig. 1 As a first step, using a segmentation algorithm, a 3D-model of the CT pelvis will defined. The anterior pelvic plane based on the **A** Spina iliaca anterior suppine right, **B** spina iliaca anterior suppine left, **C** pubicum tubercle left, **D** pubicum tubercle right will be defined manually in all three geometrical planes

were implanted on the left side and 51 on the right side. An anterolateral surgical approach was adopted in all cases, the patients being placed in the supine position. Different types of prostheses were implanted.

All of the participating centers used a CT-based hip module of the SurgiGATE-System (Medivision, Oberdorf, Switzerland). Prior to the computer-assisted surgery, all patients had a pelvic CT scan in order to determine orientation of the anterior pelvic plane defined by both anterior superior iliac spines and pubic tubercles. Using the planning part of the SurgiGATE-System, the position of first inserted acetabular cup was determined relative to this reference plane. All measurements were carried out by an independent clinical examiner.

The position of the first inserted cup was determined by a three-step procedure. First, all four reference landmarks (both anterior superior iliac spines and both pubic tubercles) were identified (Fig. 1). Then, interactively, a virtual cup was manipulated so as to mimic the position of the actual cup, which could be seen on the CT images (Fig. 2). Finally, with the anterior pelvic plane as reference and the cup position available in the computer system, both radiographic inclination and anteversion as defined by Murray et al. [18] were calculated.

The measured angles of inclination and anteversion were compared with the so-called safe zone described by Lewinnek et al. [13] (inclination angle of 40°±10° and anteversion of 15°±10°). Statistical analyses: t-test, $p<0.05$.

Results

Inclination

In the current series (n=105), the mean inclination angle was 45.8°±10.1° (range: 23.0–71.5°). The mean deviation from the 40° inclination angle was 9.47°±6.73°. Sixty-four acetabular components had an inclination within the safe zone (40°±10°). Thirty-four cups had an inclination above 50°, and seven cups had an inclination below 30°. Eight cups showed an inclination of over 60°.

Anteversion

The mean anteversion angle was 27.3°±15.0° (range: −23.5° to 59.0°). The mean deviation from the 15° anteversion angle was 15.48°±11.67°. Forty-one acetabular components had an anteversion within the safe zone (15°±10°). Fifty-nine cups had an anteversion that was higher and five one that was lower. Three cups were in a retroverted position. Taking both inclination and anteversion into consideration, only 27 cups were implanted within the safe zone.

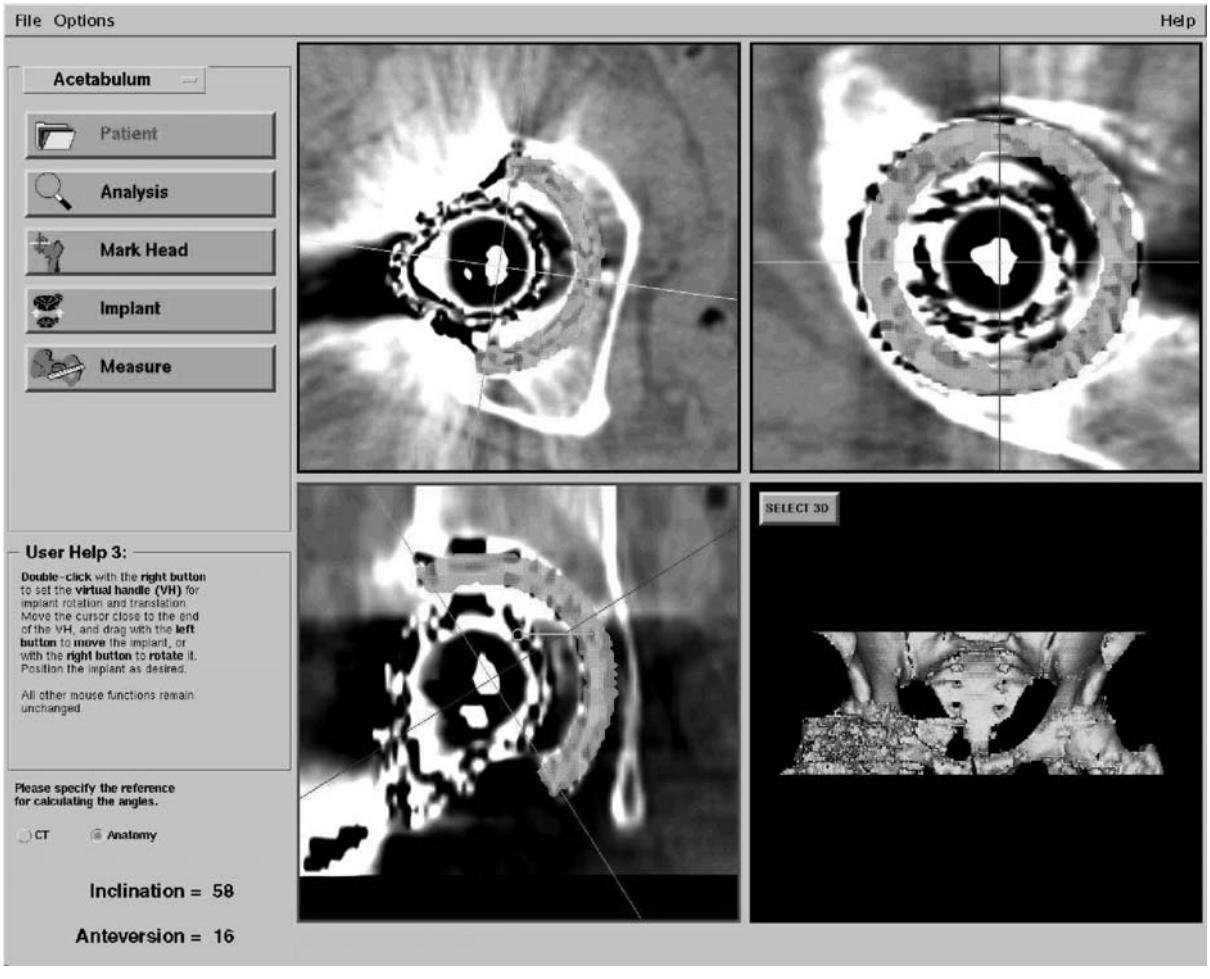

Fig. 2 The planning application of the SurgiGATE hip prosthetics module can simulate the positioning of a new cup. By placing the virtual cup onto the real implant, the spatial orientation can be calculated. Calculation according the anterior pelvic plane is recommended

Discussion

Various authors studied the correct positioning of implants [2, 4, 13, 14, 17]. Based on conventional anterior-posterior radiographs, the radiological inclination is usually measured as the angle between the longitudinal axis and the acetabular axis projected into the coronal plane [5, 13, 18]. The radiological anteversion is defined as the angle between the acetabular axis and the coronal plane [13, 18]. Recent investigation has drawn attention to the risk of missing pelvic motion when using routine radiographs [20]. Tannast et al. analyzed the influence of tilting, rotation, and obliqueness of the pelvis on measurements obtained from routine radiographs. Without a standardized reference system, significant miscalculation of the cup position was likely to occur [20]. Up to now, tilting, rotation, and obliqueness of the pelvis on the operation table have to be estimated by the surgeon during implantation. Further movement during the procedure significantly influences the placement of the cup [3]. With the introduction of the anterior pelvic plane (APP) as a reference, more reliable measurements have become available. This coordinate system uses both anterior superior iliac spines and the pubic tubercles as the reference plane. Measurements according to this reference coordinate system make reproducible measurements of cup anteversion possible [1, 3].

Lewinnek and coworkers [13] used a pelvic coordinate system with an anterior pelvic plane in order to define the so called safe zone. In the current study, the defined angles of 40°±10° inclination and 15°±10° anteversion were the basis for the evaluation of the position of freehand implanted cups.

Hirakawa et al. [6] suggested that an inclination angle lower than 40° is associated with better long-term results and fewer complications as compared to an angle of 45° or above. With a cup angle greater than 45°, a 90% mechanical failure rate was seen 15 years after cup implantation.

In the current study the mean deviation from an inclination of 40° was 9.47°±6.73°; 34 cups had an inclination above 50° and eight above 60°. Regarding anteversion, 59 cups were outside the safe zone. Surprisingly, three cups had a retroverted position, one with an angle of −23° combined with an inclination of 71°. Overall, inclination ranged from 23.0° to 71.5° (mean 45.8°) and anteversion from −23.5° to 59.0° (mean 27.3°). Our study shows that intraoperative orientation is difficult to assess. Leenders et al. [12] found a higher variability of cup inclination in conventionally implanted cups as compared to cups implanted using computer assistance. In this study, the inclination was determined using conventional radiographs.

Computer navigation systems with image-guided cup placement have been developed to increase the reliability of cup placement [1, 3, 7, 11]. Jolles' [8] in vitro studies compared freehand cup placement, placement using an alignment guide, and implantation using a computer navigation system demonstrated clearly that positioning with the computer navigation system is more precise. Other authors have reached the same conclusion [1, 11]. In this study, none of the centers used any instrument guides for implantation of the acetabular cup.

In conclusion, a safe position as defined by Lewinnek et al. [13] was only achieved in a minority of the acetabular cups that were implanted freehand.

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