Cup and Offset Navigation with OrthoPilot System

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Introduction
Optimal acetabular component orientation in total hip arthroplasty is a complex three-dimensional problem with failure leading to increased wear and instability. Recent publications have demonstrated a connection between the positioning of the prosthesis and the frequency of dislocation [1–7]. Lewinnek et al. noted an increase of the hip dislocation rate from 1.5% to 6.1% if a safe range of $15^\circ \pm 10^\circ$ radiographic anteversion or $40^\circ \pm 10^\circ$ acetabular abduction were exceeded [8]. Recent computer simulations have studied range of motion and concluded that the greatest range of motion was noted with acetabular anteversion of $20$ to $25^\circ$, acetabular abduction of $45^\circ$, and femoral stem anteversion of $15^\circ$ [1, 9, 10].

The positioning of the acetabular component during surgery is dependent on the orientation of the bony acetabulum and position of the patient’s pelvis on the operating table. McCollum et al. have stated that patient positioning is not always reproducible in the lateral decubitus position and often leads pelvic mal-alignment with resultant improper cup alignment. Pelvic flexion and adduction are virtually unavoidable in this position placing greater demands on the surgical technique for satisfactory outcome [11, 12]. Therefore, improvement in cup implantation will occur if either the pelvis position can be standardized or a method of correctly localizing the anatomical orientation of the acetabulum can be created.

Computer-assisted orthopaedic surgery has been recently defined as the ability to utilize sophisticated computer algorithms to allow the surgeon to determine three-dimensional placement of total hip implants in situ [13, 17]. A rapid ongoing evolution of technical advances have allowed the ability to move from cumbersome systems requiring a pre-operative computed tomography of the patient’s hip joint to more elegant systems that utilize image-free registration or the simple use of fluoroscopy at the time of surgery [18–20]. In total hip replacement, several reports have cited the accuracy with which implants can be placed using computer-aided robotic devices or surgical navigation [16, 17, 21, 22].

The OrthoPilot-system has been found to be reliable, and the accuracy of cup placement has been proven by several authors (Kiefer 2002; Ottersbach 2005). Since 2005 there is the opportunity to control stem position as well. In this special chapter the procedure of cup computer controlled placement combined with a movement mapping of a mayo-like neck prosthesis called Metha-stem is described.

Methods
The method of cinematic based computer controlled cup insertion is using the OrthoPilot system is described very well in the chapter 43 by Kiefer. The method of stem navigation using the same system is described by Lazovic in chapter 48. The introduction of spheric cups using a ventral minimally invasive approach needs a special angulated reamer. The acquisition of the preoperative rotational center is done first (Fig. 55.1).

To insert a neck prosthesis type Mayo-stem is a sophisticated procedure, because the femoral neck has to
be conserved performing a cut of the femoral head right beneath the border of the head.

This results in narrow space for reaming the acetabulum. So a special extension frame for the minimally invasive ventral approach is useful (Fig. 55.2). During the reaming of the acetabulum the hip is in a neutral position and 3–5 cm extension is performed after high head resection. To insert the stem, the hip is turned in 90° external rotation, adduction and hyperextension so that the neck entrance comes up and the stem insertion can be made very easily.
Using a lateral minimally invasive approach the cup insertion can be done in a normal way using a straight reamer. The stem insertion is done by external rotation of the hip.

Using the computer navigation the neutral position of the leg is taken by the pointer tip on the patella and a rigid body fixed to the major trochanter by a clamp. After insertion of the stem the stem position is collected with the pointer on the base of the neck prosthesis type Metha. This compared to the saved data of the neutral position of the hip. Afterwards a special rigid body is introduced in the conus-hole of the modular stem (Fig. 55.3). A movement mapping then can be carried out on the computer screen with helps us to decide which anteversion or retroversion of the modular conus is the best according to the offset and the ROM of the hip in relation to the saved cup position (Fig. 55.4).

Results

We performed the prosthesis in 20 cases and 19 patients since 01.01.2005 by now using the lateral approach in 11 cases and the ventral approach in 9 cases by the help of the extension frame. The 6 female and 13 male patients had an average age of 51.5 years. The neck prosthesis Metha was combined with pressfit cups type Plasmacup (Aesculap) in 15 cases and with pressfit cups type Versafit (Medacta) in 5 cases. The Metha stem was used 7 times in size 4, 4 times each in size 3 and 5, 3 times in size 2 and 2 times in size 1. Size 6 was never used.

The combined conus was in 6 times 7.5° anteversion and in 10 times 7.5° retroversion.

A neutral conus with 0° and 135° CCD-angle was used 4 times.

All the stems were implanted very well in the neck of the femur with contact of the distal tip of the stem to the lateral cortical bone right under the major trochanter (Fig. 55.5). In one case we have seen a migration of the stem towards a lower position within 6 month (11 mm) but with very well bony integration in the deeper position and without clinical problems. The navigation was successful in all the 11 cases using the lateral approach. The ventral approach needs more adaptation of the navigation tools for the movement mapping of the stem. But the navigation of the cup was possible with a curved drill even in that cases.

Discussion

Acetabular component placement in total hip arthroplasty can be difficult with optimal placement required to prevent chronic instability, exaggerated wear, and implant migration [1–5, 7, 23, 24]. Recent investigators have sought to define the radiographic analysis of cup position in the clinical setting, prosthetic issues such as range of motion and component impingement, and technical issues at the time of surgery such as body position and how to place the prosthesis in the desired location [1, 6,
Computer-assisted navigation represents a new technology that can be used to deal with all of these problems [13, 14, 22, 31].

The spatial orientation of the natural acetabulum and prosthetic components placed at surgery is a complex three-dimensional problem and most authors have attempted to describe a two-dimensional radiographic answer [32–35]. Murray has provided the most complete insight into this problem by defining geometrically

![Fig. 55.4. a Computer screen analysis image after acquisition of the stem position like a movement mapping with the virtual use of 7.5° anteversion conus, a 28 mm head as well as 130° CCD-angle and the resulting ROM and alteration of the rotational center. b Computer screen with the alternative in the same case with 7.5° retroversion and a 32 mm head as well as 140° CCD-angle and the resulting ROM and alteration of the rotational center.]

![Fig. 55.5a,b. Post-operative X-rays in two planes of a Plasmacup and a Metha stem (a ap view, b Lauenstein view).]
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exactly what these solutions represent [36]. For simple comparison, the acetabular abduction is defined as the angle formed to the transverse plane of the patient when the superior cup is tilted toward the longitudinal axis of the patient, or in the anatomical specimen a line drawn from the superior lip down to the inferior cotyloid notch on the anterior posterior radiograph. The more complex issue is how to determine the acetabular anteversion or flexion and three possibilities are possible based on how the cup is measured [17]. Operative anteversion occurs when the acetabular component is flexed in the coronal plane of the patient, essentially rotating about a line through the acetabulum which is perpendicular to the longitudinal axis of the patient. This is the maneuver accomplished by most freehand surgical guides and is the planar measurement made by determining the angulation of the cup in the frontal plane compared to the sagittal plane by looking at the coronal section CT scan [16, 17, 28]. Radiographic anteversion occurs when the anterior cup lip is rotated superiorly around the oblique transverse axis of the acetabulum which lies in the coronal plane of the patient. This measurement was typically used on cemented cups of known dimension that had wire radio-opaque markers [32, 35, 37]. A new trial to define the anatomical cup position in fluoroscopy postoperative controls is made by Ottersbach and Haaker [38]. Anatomical anteversion is the position that occurs when the abducted acetabulum position is internally rotated around the longitudinal axis of the patient. This measurement has been used to assess acetabular anatomical position in dysplasia. Murray has concluded that the operative anteversion is the most practical and should be used to describe cup position in total hip arthroplasty. For the computer application, DiGoia et al. have concluded that the operative acetabular abduction and anteversion measurements are the most straightforward reducing the conclusions to strict planar two dimensional terms [16]. We used this method for our abduction and anteversion measurements and have found no other variations in recent publications concerning computer navigation.

Lewinnek et al. were first to describe the concept of the anterior pelvic plane which is defined as a coronal slice passing through bilateral anterior superior iliac spines and the bilateral anterior pubic tubercles. In the normal standing position, this plane is usually parallel to the longitudinal axis of the patient [8]. McCollum et al. have shown that this plane may altered, especially if patients are placed in the lateral decubitus position, or there is hip flexion reducing the normal lumbar lordosis [12]. Lewinnek et al. employed a crude device with three legs and a bubble level applied to the pelvic crest and pubis to make certain that the pelvic plane was parallel to the plane of the table prior to taking their anterior posterior radiographs of the pelvis for anteversion measurement [8]. An important step in the registration procedure for computer assisted navigation is to define the anterior pelvic plane using the same references generating a standardized pelvic position [16, 17].

Numerous investigators have questioned the accuracy of standard radiographic methods for measuring cup position. For radiographic views, the X-ray beam must be carefully directed in a standardized fashion centered over the pelvis and the pelvis must be level with the beam perpendicular to the pelvic frontal plane in each case [8, 22, 35]. However, Ackland et al. stated that an error of as much as 5° could be introduced if the X-ray was centered over the symphysis pubis and not the hip joint itself [37]. Pelvic rotation certainly is an important consideration, and Thorén et al. demonstrated a 2.5° alteration of cup anteversion for 5° of pelvic rotation [34]. Herrlin et al. found that 5° of pelvic flexion or extension could introduce a maximum error of 8° in acetabular anteversion. Computed tomography assessments done with computer navigation on the other hand have been described as the »gold standard« for measuring cup abduction and anteversion with an accuracy of about 1° to 2° based on current methodologies [20, 22].

Optimum acetabular component orientation has been a subject of much debate, but most recent investigations conclude that the approximate position of 45° abduction or inclination and 20° radiographic anteversion is the ideal target. Obviously, retrospective studies such as those of Lewinnek et al. and Fontes et al. define a »safe« envelope or range about which hip stability after arthroplasty is much greater [8]. However, Barrack et al. have utilized a complex three-dimensional computer analysis to define the optimization to the above parameters and have shown that certain positions such as cup abduction below 25° or cup anteversion below 0° are clearly unsatisfactory for positions such as sitting or stooping. Acetabular stability and impingement relates not only to component position but also to prosthetic design dimensions and related femoral stem positioning [9, 25]. The average cup position after navigation in our study was acetabular inclination of 43° and cup anteversion of 22°, closely approximating the best position in the majority of cases (measured using the method of Ottersbach et al.).
DiGioia et al. used a computer-assisted navigation system similar to the method we used to study the problems of mechanical alignment in the conventional operative setting with the lateral decubitus position and with the use of typical freehand alignment guides. They found that the mean pelvic position was close to the desired anterior pelvic plane prior to dislocation, but after dislocation the pelvis tilted anteriorly causing a shift of the mean anteversion of the pelvis to 18°. Of 74 cups, 58 were placed outside the desired anteversion of 20° +/- 10° while only one cup was outside of the desired abduction of 45° +/- 10° [38]. In another study, they were able to determine that post-operative radiographs produced variable and inaccurate results compared to their precise intra-operative computer-generated measurements [17].

Concerning stem navigation, there exists only few experience and the most recent publication is made by Jerosch et al. [40] dealing with a kind of movement mapping to define the ROM after THR. Bader et al. [1, 25] could show that there is a problem of early impingement of the cone of the stem if the right anteversion and abduction of the cup is not achieved. Our first experience with the stem navigation of the Metha prosthesis shows sufficient results regarding leg length and range of motion as well as laterization and offset. The anteversion of this special kind of neck prosthesis is oriented at the anatomical anteversion and does not need any navigation help. The Goal to use it together with a minimal invasive ventral approach is an important factor to introduce this method into modern hip surgery. Further investigations are necessary to determine the usefulness of the system.

References


