

# Validity and reliability of preoperative templating in total hip arthroplasty using a digital templating system

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## Abstract

**Objectives** To evaluate the validity, interobserver reliability, and intraobserver reproducibility of a digital templating system, the Mdesk™ in preoperative templating in cemented and reverse hybrid total hip arthroplasty (THA).

**Materials and methods** Validity was evaluated by comparing the planned cup size, stem size, CCD angles, and neck length with the components used in 129 patients operated with cemented and reverse hybrid THA. The reliability was measured by comparing the templating results of two surgeons with each other (interobserver) and the results of two templatings carried out by first surgeon (intraobserver). The leg length discrepancy was measured before and after the operation to assess the templating ability to correct it.

**Results** The Mdesk™ system showed good validity (kappa value ranged from 0.64 to 0.96), especially when one size over and under the planned size were included. No difference between cemented and cementless stems was found. The interobserver reliability ranged from fair (kappa 0.23) to substantial (kappa 0.61) while the intraobserver reproducibility

ranged from substantial (kappa 0.70) to excellent (kappa 0.82). Templating and intraoperative measures succeeded to restore the leg length.

**Conclusions** The Mdesk™ system has comparable validity and reliability with other templating systems used in clinical practice. We recommend that the same surgeon who does the preoperative radiographic templating to also perform the operation. Further studies are required to evaluate the results of succeeded templating in the long run.

**Keywords** Templating · Hip arthroplasty · Validity · Interobserver reliability · Intraobserver reproducibility · Mdesk™

## Introduction

The use of preoperative templating in total hip arthroplasty (THA) has gained increasing importance in clinical practice during the last two decades. Different templating methods have been advocated to assist surgeons choosing the most appropriate implant sizes and positioning. With proper templating, many goals might be achieved. For instance, restoration of the hip biomechanics and soft-tissue tension with suitable offset and minimal leg length discrepancy (LLD), improvement of range of motion and stability, decreasing the incidence of intra-operative peri-prosthetic fractures, shortening the operative time and finally enhancing the implant's longevity by decreasing wear caused by mal-positioning of the implant components [1–4]. Moreover, the wide range of types and modularity of the available prostheses in the market makes preoperative templating especially important to limit any one-hospital unit in stocking large inventories of implants.

Preoperative templating is carried out by different methods. Hardcopy (analogue) radiographs and transparent

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magnified onlay templates have been widely used to measure the size of the implant. The validity (accuracy) and reliability of this method are well documented in the literature despite the fact that the degree of radiographic magnification in correlation to the used templates may represent a source of error in predicting the accurate components [5–8]. Furthermore, this method is rather impractical nowadays owing to the implementation of digital image-acquisition techniques and digital image review as a standard modality in most hospitals. With digital templating, radiographs are displayed in a PACS (Picture Archiving and Communication System) monitor where special software packages are available to choose the suitable type, size, and positioning of the implant. The degree of magnification can also be assessed using a spherical radio-opaque ball with a known diameter placed in the X-ray field as a reference. The precision and reliability of different software packages in digital templating of cemented, cementless, and resurfacing THA have been studied and documented [9–15].

The purpose of the present study was to evaluate the validity, interobserver reliability, and intraobserver reproducibility of the Mdesk™ system (RSA Biomedical, Umeå, Sweden) in preoperative templating in cemented and reverse hybrid THA. This system was first introduced in 2004 and has been popular in different European countries. To our knowledge, this is the first report to evaluate this system.

## Materials and methods

Between 2007 and 2010, one surgeon operated 154 consecutive patients with unilateral cemented or reverse hybrid THA. Preoperatively, the AP pelvic radiographs were standardized by keeping the feet in 15° of internal rotation with fixed source to film distance. For calibration, a radio-opaque ball of 30 mm in diameter fixed with a belt around the inner aspect of the thigh nearest possible to the pelvis was used. One to two days before surgery, the surgeon carried out templating by importing the AP pelvic radiographs from PACS to the Mdesk™ system program where digital templates (obtained from the manufacturer) were placed over the digital images. Templating was started by image calibration using a standard a 30-mm metal ball. The pelvic plan was obtained by drawing a line between the teardrops medial to the acetabula. The lesser trochanters and center of rotation were specified. Thereafter, the following measurements were obtained: the cup size, stem size, neck length, and CCD angle as well as LLD. The templated radiographs were saved as Mdesk™ file in a dedicated database for further analysis (Fig. 1). The study was approved by the local ethical committee.

During the operation, the surgeon had a copy of the templated pelvic radiograph as a reference. The posterolateral

approach was used in all patients. The final decision of the used components was taken according to the intra-operative anatomical parameters, e.g., degree of sclerosis and quality of cancellous bone, tension of surrounding soft tissue, and implant stability. Intra-operative LLD was measured using jigs between a pin placed cranial to the acetabulum and a mark on the greater trochanter. The distance between these two points was measured before and after implanting the prosthetic components taking into consideration the amount of lengthening/shortening intended to be achieved by the operation (Fig. 2).

In order to evaluate the validity of preoperative templating, we compared the predicted sizes by the templating with the used sizes operatively. The leg length discrepancy (LLD) was also measured as the difference in perpendicular distance in millimeters between a line passing through the lower edge of the teardrop points to the corresponding tip of the lesser trochanter. A positive LLD value was obtained when the planned side for operation was longer than the contralateral side, whereas a negative value indicated the opposite. A 1-mm precision scale was used.

To measure the intraobserver reproducibility, the surgeon re-templated 60 radiographs chosen randomly from the cohort 3 months after the first templating. Another surgeon templated the same 60 radiographs. The surgeons were blinded to each other's results. The results of the two surgeons were compared to each other to evaluate the interobserver reliability.

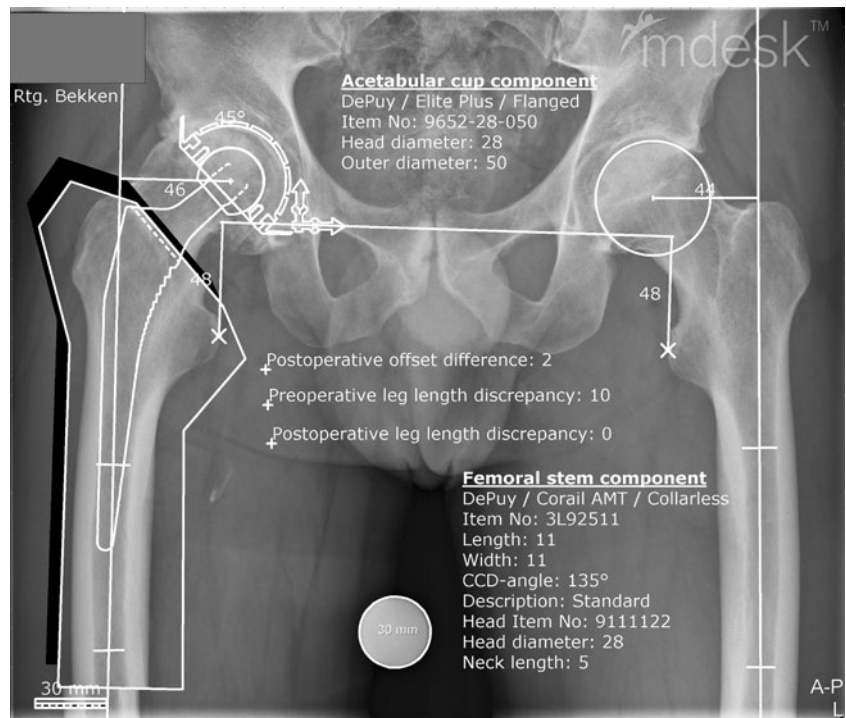
Both surgeons have good experience using the Mdesk™ system. Before starting the study, the two surgeons went through the templating technique and did a dozen of cases to standardize the measurements.

## Statistical analysis

SPSS version 16 (SPSS, Chicago, IL, USA) was used for statistical analysis. The validity, interobserver reliability, and intraobserver reproducibility of the Mdesk™ system were evaluated by Cohen's kappa.

The kappa value is an appropriate measure for reliability and reproducibility studies involving categorical data (sizes in the present study), compared with intra-class correlation co-efficient (ICC), which is used for continuous data. As with ICC, the interpretation of kappa value is, however, controversial. According to Hornij [16], values exceeding 0.75 represent excellent agreement, 0.4–0.75 fair to good agreement, and values less than 0.4, poor agreement. Rheault et al. [17] used the criteria recommended by Landis and Koch [18] (0.00–0.20 slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–1.00 excellent agreement). Others [19] considered the value of 0.60 as a limit of acceptability for application in clinical practice. We chose to use the criteria recommended by Landis and Koch [18].

**Fig. 1** Preoperative templating on the AP view of the pelvis. The calibration marker is placed at the upper inner thigh. The sizes of the cup and stem, leg length, femoral offset, and center of rotation are measured



**Results**

Twenty-five patients were excluded due to lack of standardized radiographs such as calibration object or asymmetry at the AP view. One hundred and twenty-nine patients (85 females and 44 males, with a mean age of 66 years) were therefore included. The implants used were cemented Lubinus™ SPII® Hip

System (LINK, Germany) in 78 patients and reversed hybrid Corail® femoral cementless stem and Elite Plus Ogee (DePuy, Johnson & Johnson, UK) cemented acetabular cup in 51 patients. The available sizes of components for use are listed in Table 1.

**Validity**

For the femoral stem, the same planned size was used in 82 patients (64 %), kappa=0.67. No difference was found between cemented and cementless stems (51/78 vs. 31/51, p=0.70). When ± one size of the planned size was included, templating chose the right size in 122 patients (95 %). For the acetabular cup, the same planned size was used in 77 patients (60 %), kappa=0.64. When ± one size of the planned size was included, templating chose the right size in 121 patients (94 %). For the neck length, the same



**Fig. 2** Postoperative radiographic control showing the used components. In this case, the templating predicted the right size of the cup, stem, CCD angle, and neck length. The LLD was within 5 mm

**Table 1** The available sizes of the used components

Components	Available sizes for use
Lubinus cemented stem	01, 1, 2, 3, 4, 4A
Lubinus cemented cup	46, 48, 50, 52, 54, 56
Corail cementless stem	8, 9, 10, 11, 12, 13
Elite Plus Ogee cemented cup	46, 48, 50, 52, 54, 56
Lubinus stem CCD angle	117, 126
Corail stem CCD angle	Standard, high offset
Lubinus neck length	46, 49.5, 53, 60
Corail neck length	–3.5, 0, 3.5

planned size was used in 91 patients (71 %),  $\kappa=0.62$ . For the CCD angle (117 vs. 126 and standard vs. high offset), the kappa value reached 0.96.

The mean preoperative planned LLD was 1.5 mm (SD 3.8 mm) while the obtained postoperative LLD was 0.5 mm (SD 4.5 mm),  $p=0.20$ .

#### Interobserver reliability

For the femoral stem, the two surgeons chose the same size in 57 % of cases ( $\kappa=0.61$ ), the same acetabular cup size in 35 % of cases ( $\kappa=0.41$ ), the same neck length in 52 % of cases ( $\kappa=0.23$ ) and the same CCD angle in 83 % of cases ( $\kappa=0.46$ ).

#### Intraobserver reproducibility

For the femoral stem, the surgeon chose the same size in 73 % of cases ( $\kappa=0.81$ ), the same acetabular cup size in 60 % of cases ( $\kappa=0.70$ ), the same neck length in 77 % of cases ( $\kappa=0.71$ ) and the same CCD angle in 93 % of cases ( $\kappa=0.82$ ).

## Discussion

Total hip arthroplasty is one of the most successful and cost-effective procedures in orthopedics. Preoperative clinical and radiological planning is an essential step for this success. It allows the surgeon to anticipate any possible difficulty that might arise during the operation. Despite the limited types and sizes of available implants during the 1970s, preoperative planning was even recommended at that time by Charnley [20] and Muller [21]. For many years thereafter, conventional radiographs had been used for preoperative templating. Many authors have tested the accuracy and reliability of this modality. Knight and Atwater [5], for example, used conventional radiographs to template 110 cementless and hybrid total hip arthroplasties. They found that implant sizing was predicted for 62 % of acetabular cups, 78 % of cemented stems, and 42 % of the cementless stems. Leg-length equalization was achieved in only 70 % of cases. Eggli et al. [1] reported the component sizes could be predicted in 90 % of cases where more than 90 % of the cases in the series used cement fixation. For cementless prostheses, Carter et al. [6] reported that the exact size of femoral components was predicted in approximately 50 % of 74 cases. Also, Gonzalez Della Valle et al. [7] showed that the templated size corresponded to the actual component used approximately 78 % and 83 % for cemented femoral prostheses and combined cemented and cementless acetabular components, respectively. Suh et al.'s [8] results agreed with the above-mentioned studies. In almost all

reports, the predictive validity of preoperative templating markedly improved when within  $\pm$  one size of the plan was used [22].

The introduction of digital imaging in clinical practice has been associated with numerous advantages, e.g., secured storage of radiographs, easier manipulation and magnification calibration and availability for simultaneous viewing and data transfer to other hospitals as well as cheaper processing and production costs. The manufacturing hip implant companies provide many digital programs utilizing software with digital templates. The validity and reliability of these programs in digital templating have been reported and compared to those obtained from analogue templating. While The et al. [23] and Gamble et al. [11] found that digital templating slightly outperformed analogue templating with more accurate cup size planning, others [12, 24] found digital templating being as accurate and reliable as the conventional templating. Della Valle [25], on the other hand, reported more predictable results with analogue preoperative planning than digital planning in terms of acetabular component size and limb lengthening-shortening.

In the present study, the validity of the Mdesk™ system to predict the cup size was slightly lower than for the stem size. The templating values markedly improved when within  $\pm$  one size of the plan was used. This concurs with the results of Steinberg et al. [13] who used the TraumaCad™ system and the results of Efe et al. [15] who used the MediCad™ system. This slight difference between the cup and stem sizing can be explained by the relative difficulty to position the cup and to decide the degree of subchondral bone removal and the space for cement mantle. However, Davila et al. [9] used the EndoMap™ system and found better validity for cup sizing than stem sizing. Moreover, previous studies gave diverging data about the validity for cemented versus cementless stems. Some authors think cementless stems are more demanding to template, as they require exact press-fit insertion in the femoral metaphysis and medullary canal. This depends also on the bone quality, which is usually difficult to evaluate on preoperative radiographs. Others think that cemented stems are more difficult to plan, as the surgeon must take the place for a cement mantle into consideration. In the present study, we found no statistical difference in the validity of templating between cemented and cementless stems. The validity of neck length templating was good ( $\kappa$  0.62). The authors consider this part rather demanding as the neck length is affected by positioning of the cup and stem and osteotomy cut level as well as the plan to lengthen or shorten the operated limb. For the CCD angles, excellent validity ( $\kappa$  0.96) was reached.

Leg-length discrepancy after THA is a common cause for patient postoperative dissatisfaction and may lead to litigation. Surgeons consider postoperative LLD within 10 mm as an acceptable limit. In the present study, the postoperative LLD was 0.5 mm with a SD of 4.5 mm). This means that our

preoperative radiographic templating and intraoperative LLD jig measurement were successful to restore the leg length.

Regarding reliability, the intraobserver reproducibility ( $\kappa$  values 0.70 to 0.81) was better than the interobserver reliability ( $\kappa$  values 0.23 to 0.61) for all tested parameters (cup size, stem size, neck length, and CCD angle). This agrees with previous studies [23, 24]. One explanation is that each individual surgeon has their own templating technique and knows what works best for his/her cases. We recommend, therefore, that the same surgeon who makes the preoperative templating perform the operation.

The present study has some limitations. First, we assumed the implanted prosthesis was always the optimal size, which might not have been the case. Second, no biomechanical or long-term outcome parameters were measured to evaluate the effect of more accurate planning in the long run. Third, the number of observers (two for interobserver measurements) is small. However, the prospective nature of the study and the large number of included measurements compensate for these limitations.

## Conclusions

The Mdesk™ system showed good validity and reliability; especially when within  $\pm$  one size of the plan was used. It is recommended that the same surgeon who does the preoperative radiographic templating to perform the operation. Templating and intraoperative jig measurement of leg length succeeded to restore LLD to within 10 mm. Further studies are required to evaluate the results of succeeded templating in the long run.

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