Morbidly Obese Patients Undergoing Reduced Cup Anteversion Through a Direct Lateral Approach

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Background: The presence of obesity negatively affects the results after total hip arthroplasty. The influence of morbid obesity on cup positioning is investigated.

Methods: A retrospective analysis of radiographs from 790 patients in 2013 and 2014 was performed. The correlation of cup inclination and anteversion with body mass index (BMI) was analyzed. Three groups were formed: 139 patients with normal weight (BMI of <25 kg/m²), 566 patients with moderate obesity (BMI between 25 and 34 kg/m²), and 85 patients with morbid obesity (BMI of ≥35 kg/m²).

Results: Cup anteversion significantly correlated with BMI (R = −0.127, p < 0.001) and patient age (R = 0.115, p = 0.001). This corresponded with a reduction of anteversion by 3.4° (p < 0.001) in the morbidly obese group compared with the normal-weight group. Cup inclination was not influenced by BMI or patient age.

Conclusions: The precision of cup positioning declines with increasing obesity. In addition, significantly reduced anteversion is found in younger patients. We assume that this is due to iatrogenically changed pelvic tilt resulting from increased pressure exerted on the dorsal and ventral acetabular rim retractors.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

The proportion of obese individuals in the world population has more than doubled since 1980. In 2014, 1.9 billion people among the total of the world’s population, or 39% of all adults (≥18 years of age), were overweight, with a body mass index (BMI) of ≥25 kg/m². Of all adults, 13% (600 million) were considered obese.

Obesity plays a major role in the outcome of total hip arthroplasty. In the New Zealand Joint Registry, a poorer survival of total hip replacements was demonstrated in obese patients. In contrast to this, the influence of obesity on the outcome in individual studies is the subject of considerable debate. Jackson et al. and Tai et al. did not find any influence of obesity on survival in cementless total hip replacements. However, Jameson et al. showed a negative influence of BMI on patient-reported outcome measures and complications after total hip arthroplasty. In a current meta-analysis of prospective cohort studies, it appears that obesity has a negative influence on the overall complication rate, dislocation rate, functional outcome, and operative time of primary total hip arthroplasty.

In particular, the less favorable positioning of the cup component is believed to be the cause of poorer results in obese patients. An incorrect cup positioning entails not only an increased risk of dislocation but also a greater risk of early implant wear due to increased friction.

It remains unclear what influence BMI has on implant positioning. Pirard and De Lint, Todkar, and Bosker et al. failed to detect any influence of BMI, but Callanan et al. and Elson et al. found the reverse to be true.

Two problems arise in the interpretation of different studies. In almost all studies, the posterior approach is used exclusively. It permits excellent exposure, but is not preferred by all surgeons. Minimal data are available on lateral or anterolateral approaches, although a transfer of the results from the posterior to the lateral approach is questionable when considering cup positioning.

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To our knowledge, the evidence obtained to date has been mainly based on case series and register studies, which are limited in their informative value by potential confounders. The main problem is the significantly younger age of obese patients in all studies, which prevents a differentiation between age-associated and weight-associated effects\(^\text{17}\).

In a matched-pair study, which exclusively considered the posterior approach, Tai et al. could not demonstrate a negative effect of BMI on the outcome\(^\text{4}\). In a matched-pair study conducted by Elson et al., various approaches were used, but without matching of the approach and with marked underrepresentation of the lateral approaches\(^\text{5}\).

Therefore, the objective of the present study was to investigate the influence of obesity on the cup position when using a lateral approach, for the first time including patient age in a multivariable analysis.

### Materials and Methods

Differences in implant positioning in patients with slim and obese physiques were investigated in this study. Since January 2013, our department has electronically recorded the height and weight of each patient. Therefore, all patients who underwent cementless total hip arthroplasty in 2013 and 2014 due to primary osteoarthritis of the hip were recorded and were retrospectively evaluated. Other indications (e.g., dysplasia, secondary hip osteoarthritis, or revision operations) were excluded, as were cemented or hybrid implants. Previous operations involving the hip joint were also an exclusion criterion. Thus, patients were only included if an increased degree of difficulty of cup positioning due to anatomical anomalies was not to be expected. A total of 867 patients were identified accordingly in these 2 years. From these, 790 patients had complete records, including standardized postoperative radiographs, and were included in this investigation.

The transgluteal approach according to Bauer et al. was used\(^\text{18}\). The operation was performed with the patient in the supine position (n = 687) or the lateral position (n = 103), according to the surgeon’s preference. The implant positioning was determined retrospectively on the basis of low pelvic overview radiographs in the anterior-posterior ray path and lateral images of the hip joint, which were prepared approximately 7 days postoperatively. The software MediCAD Classic (version 2.55; Hectec) was used for this purpose. The inclination and anteversion of the cup position were evaluated by an individual who was blinded to patient BMI. Because the differentiation of the version into anteversion and retroversion is not possible on radiographs in one plane, we assumed all version to be anteversion. In all cases, an inclination of 40° and an anteversion of 15° were anticipated. With regard to the stem position, the varus and valgus angle and any postoperative difference in lower-limb length were measured. Implant-specific data on the cup and head size were recorded. In addition, sex distribution, the age of the patients at the time of the surgical procedure, the duration of the surgical procedure, blood loss, and postoperative complications such as wound-healing disorders, infections, dislocations, thromboses, and pulmonary emboli were recorded.

The presence of correlations for cup inclination and anteversion with BMI and patient age was tested. Therefore, a stepwise linear regression analysis was performed including the parameters showing a significant correlation with cup anteversion. Three groups were then formed: 139 patients (17.6%) with normal weight (BMI of <25 kg/m\(^2\)), 566 patients (71.6%) with moderate obesity (BMI of 25 to 34 kg/m\(^2\)), and 85 patients (10.8%) with morbid obesity (BMI of ≥35 kg/m\(^2\)) (Table I).

The mean age (and standard deviation) was 70.9 ± 8.0 years (range, 40 to 85 years) for the normal-weight group, 70.3 ± 7.7 years (range, 40 to 85 years) for the moderately obese group, and 66.6 ± 9.6 years (range, 46 to 84 years) for the morbidly obese group (p = 0.001).

The examination groups were compared using the Mann-Whitney U test. For dichotomous variables (e.g., inside or outside a safe zone), the chi-square test was used. All statistical tests were performed at a level of significance of p < 0.05.

### Results

Patients in the morbidly obese group were significantly younger than those in the normal-weight or moderately obese groups (p = 0.001). The sex distribution did significantly differ between the normal-weight group and the moderately obese group (p = 0.032 in the chi-square test), but did not differ between the normal-weight group and the morbidly obese group (p = 0.210).

Cup inclination was not correlated with BMI or patient age. In contrast, cup anteversion was significantly correlated with BMI (R = −0.127, p < 0.001) and patient age (R = 0.115, p = 0.001). In a stepwise linear regression analysis, only BMI and patient age were identified as being independent influencing parameters for cup anteversion, with increasing BMI and decreasing patient age resulting in a decreasing cup anteversion (combined model, R = 0.16).

Within the context of the training commitment of an academic teaching hospital, 23 surgeons were involved. A possible systematic error produced by an individual surgeon is therefore more unlikely than in a single-surgeon setting.

The mean follow-up of the patients was 15 months (range, 2 to 29 months). The mean inclination was 41.5° ± 6.5° in the normal-weight group, 42.8° ± 6.5° in the moderately obese group, and 42.8° ± 6.6° in the morbidly obese group, and these differences were not significant (p > 0.05). The mean anteversion was 13.4° ± 6.7° in the normal-weight group, 12.0° ± 6.3° in the moderately obese group, and 10.0° ± 6.8° in the morbidly obese group; the anteversion differences were significant when

### Table I Patient Demographic Data

<table>
<thead>
<tr>
<th>BMI</th>
<th>Age* (yr)</th>
<th>Male Patients†</th>
<th>Female Patients†</th>
<th>Total†</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25 kg/m(^2)</td>
<td>70.9 ± 8.0</td>
<td>52 (37.4%)</td>
<td>87 (62.6%)</td>
<td>139 (17.6%)</td>
</tr>
<tr>
<td>25 to 34 kg/m(^2)</td>
<td>70.3 ± 7.7</td>
<td>269 (47.5%)</td>
<td>297 (52.5%)</td>
<td>566 (71.6%)</td>
</tr>
<tr>
<td>≥35 kg/m(^2)</td>
<td>66.6 ± 9.6</td>
<td>39 (45.9%)</td>
<td>46 (54.1%)</td>
<td>85 (10.8%)</td>
</tr>
</tbody>
</table>

*The values are given as the mean and the standard deviation. †The values are given as the number of patients, with the percentage in parentheses.
the morbidly obese group was compared with the normal-weight group (p < 0.001) and when it was compared with the moderately obese group (p = 0.041). Given an equal standard deviation, this corresponds to a systematic inadvertent reduction of anteversion in morbidly obese patients by 3.4° compared with normal-weight patients (Fig. 1).

The results found were independent of the surgeon and of the patient position (supine or lateral decubitus). The mean cup anteversion was 12.3° ± 7.1° when the surgical procedure was performed with the patient in a lateral position and 12.1° ± 6.8° when it was performed with the patient in a supine position, and this difference was not significant (p > 0.05). An intersurgeon comparison did not show a significant difference (p > 0.05) in cup anteversion in the Kruskal-Wallis test.

If one assumes the safe zone for the positioning of the acetabulum according to Lewinnek et al. as the anticipated target value of inclination at 40° ± 10° and anteversion at 15° ± 10°, 75% of the normal-weight patients and 75% of the moderately obese patients were within this zone. However, only 59% of the morbidly obese patients were within this zone (Fig. 2). This difference was significant (p = 0.014 in the chi-square test).

In contrast to this, no difference was found between the groups when the zone for optimal cup position defined by Callanan et al. was taken as a basis. Here, only 55% of the normal-weight group, 54% of the moderately obese group, and 45% of the morbidly obese group had a cup position defined as optimal, and this difference was not significant (p > 0.05).
The mean duration of the surgical procedure was 13 minutes longer in the morbidly obese group (76.2 ± 20.4 minutes) compared with the normal-weight group (63.6 ± 18.7 minutes), and the difference was significant at p < 0.001.

The operatively treated limb averaged 2.5 ± 6.2 mm longer in the normal-weight group, 2.1 ± 5.1 mm longer in the moderately obese group, and 1.3 ± 6.6 mm longer in the morbidly obese group than the contralateral limb in each of these three groups, and these differences were not significant (p > 0.05). The mean absolute value of the lower limb-length discrepancy was 5.1 ± 4.4 mm in the normal-weight group, 3.7 ± 4.2 mm in the moderately obese group, and 5.0 ± 4.4 mm in the morbidly obese group, and the differences were also not significant (p > 0.05).

The absolute value of stem alignment in the frontal plane did not differ among the groups. The stem alignment ranged between 3.6° valgus and 4.3° varus in the normal-weight group, between 5.7° valgus and 6.3° varus in the moderately obese group, and between 4.1° valgus and 4.3° varus in the morbidly obese group, and the differences were not significant (p > 0.05).

The cup sizes did not differ among the examination groups. In the normal-weight group, 28-mm heads were used in 9 hips (6.5%), 32-mm heads were used in 57 hips (41.0%), and 36-mm heads were used in 73 hips (52.5%). In the moderately obese group, 28-mm heads were used in 28 hips (4.9%), 32-mm heads were used in 198 hips (35.0%), and 36-mm heads were used in 25 hips (4.9%), and 32-mm heads were used in 198 hips (35.0%), and 36-mm heads were used in 25 hips (4.9%), and 32-mm heads were used in 198 hips (35.0%), and 36-mm heads were used in 25 hips (4.9%), and 36-mm heads were used in 25 hips (4.9%). In the morbidly obese group, 28-mm heads were used in 2 hips (2.4%), 32-mm heads were used in 25 hips (29.4%), and 36-mm heads were used in 58 hips (68.2%).

Blood loss did not differ among the study groups. No patients had a dislocation of the hip during the study period.

In the morbidly obese group, 4 complications were recorded (4.7%). In 1 male patient (1.2%), an avulsion fracture of the greater trochanter occurred during inpatient rehabilitation. This was treated surgically by refixation of the fragment with cerclage wiring. In 1 female patient (1.2%), subsidence of the femoral stem occurred during the period of inpatient treatment, leading to a periprosthetic spiral fracture that had to be treated by replacement of the stem. During the follow-up period, a periprosthetic infection occurred in this patient, with removal of the prosthesis and reimplantation in 2 stages. One male patient (1.2%) showed wound dehiscence that required revision.

In the moderately obese group, 18 complications were documented (3.2%). These complications included 5 revisions (0.9%) due to hematoma or wound dehiscence, 3 lesions of the sciatic nerve (0.5%), and 1 lesion of the femoral nerve (0.2%). Except for 1 sciatic nerve lesion, all were reversible over the course. There was 1 fracture of the greater trochanter (0.2%), which was treated conservatively, and 2 intraoperative fractures of the femoral shaft (0.4%), which were treated by cerclage wiring. One early infection (0.2%) was successfully treated by a staged surgical revision. Two deep venous thromboses (0.4%) and 1 pulmonary embolism (0.2%) were recorded. One patient (0.2%) died because of paralytic ileus and perforation of the colon ascendens.

In the normal-weight group, there was 1 early infection, which was treated successfully by means of debridement as well as replacement of the head and liner (0.7%). Intraoperative or postoperative fractures were not observed in this group. The complication rates did not differ significantly among the 3 groups (p > 0.05).

Discussion

The increasing number of obese individuals in the population will pose major socioeconomic challenges for the developed countries. Obesity is associated with longer hospitalization and with higher total costs in total hip arthroplasty. With obesity as one of the predictors of hip osteoarthritis, an increasing number of overweight patients requiring implantation of a total hip replacement is also to be expected. The precision of implant positioning is a major factor for the long-term outcome after total hip arthroplasty.

As early as 1997, it was shown that a smaller contact surface in dysplastic or steeply inclined acetabula resulted in higher peak contact forces than in normal acetabula. In the case of steeply inclined acetabula, these forces can lead to increased polyethylene wear. When ceramic-on-ceramic articul ar pairings are used, excessive inclination leads to the risk of squeaking and ceramic fractures because of edge-loading.

Patil et al. were able to show that increased inclination is not only associated with increased wear. Decreased antever sion also leads to higher peak contact forces, which lead to increased wear.

However, in our study, we are able to show that this precision in cup anteversion but not inclination decreases with increasing obesity. As early as 1978, Lewinnek et al. defined a safe zone for positioning of the acetabulum at 40° ± 10° inclination and 15° ± 10° anteversion. This historical article continues to be cited regularly and is considered to be the gold standard for positioning of the acetabulum. In a more recent study, Callanan et al. defined the limits for an optimal cup position more tightly at an inclination of 30° to 45° and anteversion identical to that of Lewinnek. However, as a whole, there is no clear consensus on optimal cup positioning in the literature. If one specifies the safe zone according to Lewinnek as a target value, a significant difference was found in the present study between the normal-weight group (BMI of <25 kg/m²) or moderately obese group (BMI between 25 and 34 kg/m²) and the morbidly obese group (BMI of ≥35 kg/m²). Contrary to expectations, no significant differences were found when cup inclination was considered alone. However, resulting from a significant correlation between BMI and cup anteversion, there was a significantly lower anteversion in the morbidly obese group than in the normal-weight or moderately obese groups. In the present study, we could not show a higher dislocation rate in morbidly obese patients with lower anteversion in the short-term follow-up. Nevertheless, the findings are clinically important regarding long-term implant survival. Therefore, an accurate placement of the acetabular component seems to be indispensable, especially in the growing population of young, morbidly obese patients.
Elkins et al. also demonstrated a reduced anteversion in obese patients. They explained their results with reduced vision in the surgical field in obese patients and thus more difficult identification of osseous landmarks.

However, we assume the cause to have been an iatrogenically changed pelvic tilt resulting from the pressure applied to the dorsal and ventral acetabular rim retractors when impacting the cup. In our department, the view of the acetabulum is usually ensured by using 3 acetabular rim retractors. One is positioned ventrally, 1 is positioned caudally, and 1 is positioned dorsally on the acetabular rim. In the case of obese or very muscular patients, experience has shown that pressure on the dorsal and ventral retractors has to be increased considerably to ensure good vision. Asayama et al. demonstrated a significant pelvic lift of >14° by application of an anterior Hohmann retractor. It may therefore be assumed that the pressure on the retractor directly influences the lifting of the ipsilateral pelvis. Although the same cup anteversion was anticipated for all patients (through orientation in space), this effect may explain the reduced actual cup anteversion in obese patients. The anteversion may thus depend on the amount of soft tissue and the relative proportion of muscle.

This explanatory model for our results is also favored by the age dependency of cup anteversion that was also shown. Age alone as well as age in combination with BMI in a linear regression model correlated with cup anteversion. With increasing age, the relative muscle mass declines. Muscle offers the retractor a stronger abutment than fat and thus indirectly ensures a reduced cup anteversion by increasing the lifting of the pelvis.

In the lateral approach, the impaction of the cup should be performed with slackened acetabular rim retractors to prevent an iatrogenic tilting of the pelvis. In addition, more anteversion should be set in young and obese patients than one would suspect intraoperatively to achieve the anticipated goal.

Further investigations are necessary to verify the suspected iatrogenic influence of pelvic tilting during exposure of the acetabulum. Although the difference in cup anteversion was relatively low (3.4°) and specific complications were not different among the groups, it cannot be concluded that it is irrelevant. On the basis of the limited number of patients and the overall low incidence of dislocations, the study design was not appropriate to detect differences in the dislocation rate between obese and normal-weight patients or a correlation between the dislocation rate and cup anteversion. In a long-term follow-up, a reduced cup anteversion may be associated with a higher rate of polyethylene wear. On the basis of the study results, the knowledge of a systematic error in obese patients should raise surgeons’ awareness of the need to perform cup implantation with greater attention.


